2018 Annual Report
Tacoma Landfill
Tacoma, Washington

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Prepared for

Solid Waste Management Division
City of Tacoma
Tacoma, Washington

Landau Associates

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LIST OF ABBREVIATIONS AND ACRONYMS

µg/L	microgram per liter
BTU/hr	British thermal units per hour
CD	Consent Decree
City	City of Tacoma, Washington
cm/sec	centimeters per second
COC	contaminant of concern
CW	central west
Ecology	Washington State Department of Ecology
EPA	US Environmental Protection Agency
ft/min	feet per minute
GCCS	the gas collection and control system
GETS	groundwater extraction and treatment system
gpd/acre	gallons per day per acre
HD	Home Depot
HDPE	high-density polyethylene
IC	institutional control
LAI	Landau Associates, Inc.
LEL	lower explosive limit
LFG	landfill gas
O&M	operations and maintenance
OU	operable unit
PCC	post-closure care
PCE	tetrachloroethene
POC	point of compliance
PVC	polyvinyl chloride
ROD	record of decision
SOW	scope of work
SVOC	semivolatile organic compound
SWM	City of Tacoma's Solid Waste Management Division
TCE	trichloroethene
TLF	Tacoma Landfill
TPCHD	Tacoma-Pierce County Health Department
VOC	volatile organic compound
WAC	Washington Administrative Code

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1.0 INTRODUCTION

Landau Associates, Inc. (LAI) prepared this Annual Report, which summarizes 2018 post-closure care (PCC) operations and maintenance (O&M) activities at the Tacoma Landfill (TLF). The TLF is located at 3510 South Mullen Street in Tacoma, Washington. The City of Tacoma (City) Solid Waste Management Division (SWM) has operated the TLF as a sanitary landfill since about 1960. The TLF was effectively closed to landfilling waste in November 2013 and went into PCC status in April 2017. SWM currently operates the TLF under a permit with the Tacoma-Pierce County Health Department (TPCHD) in accordance with provisions of Chapters 173-304 and 173-351 of the Washington Administrative Code (WAC). In accordance with the TPCHD permit, the City has a PCC plan (LAI 2016d). Aside from PCC of the closed landfill, other ongoing TLF property uses include a refuse compaction/ transfer center, a household hazardous waste facility, a recycling center, an environmental education facility, SWM offices, and a golf driving range.

The location of the TLF is shown on Figure 1. The Landfill is segmented into six areas: Northeast, Northwest, Central East, Central West, South, and Central Area based on filling history and geographic proximity. The sequence of filling at the Landfill is shown on Figure 2. Landfill areas are shown on Figure 3.

1.1 Background

The TLF was placed on the National Priorities List in 1983 by the US Environmental Protection Agency (EPA) as part of the Commencement Bay/South Tacoma Channel Federal Superfund Site. Within the TLF Superfund Site, the EPA designated two operable units: OU5 Source Control and OU6 Groundwater Remedy. OU5 includes the landfill cap system (surface to liner) and OU6 includes the groundwater monitoring network and groundwater extraction and treatment system (GETS).

A final remedy to address landfill contamination was documented in a 1988 Record of Decision (ROD; EPA 1988) issued by the EPA. Remedial actions have been carried out by the City under a 1991 Consent Decree (CD; DOJ 1991) with the EPA and the Washington State Department of Ecology (Ecology). The final remedy is in-place and includes environmental control and monitoring facilities required for PCC. The City is implementing PCC practices documented in the CD and WAC 173-351-500 required by its permit with TPCHD.

1.2 Post-Closure Care Program Overview

The PCC program includes O&M of the final remedy environmental controls and monitoring facilities. These controls and facilities include landfill caps (Figure 3), landfill and cap leachate control (Figure 4), landfill gas system (Figure 5), GETS (Figure 6), and a groundwater/surface water monitoring network (Figure 6). The guiding PCC plans for 2018 included the following:

- Environmental Operations Plan (LAI 2016b), regarding the overall cap system (surface and subgrade)

- Leachate and Condensate Management Plan (LAI 2016c)
- Draft 2017 Post-Closure Landfill Gas Management Plan (LAI 2017a)[1]
- Post-Closure Groundwater and Surface Water Compliance Monitoring Plan (LAI 2014c)
- Post Closure Water Quality Monitoring Sampling and Analysis Plan (LAI 2017b)
- Tacoma Landfill Institutional Controls Plan (City of Tacoma 2012).

These plans were used during 2018 PCC activities. In addition, groundwater rebound monitoring activities were completed in 2018 and the guiding plans were:

- Tacoma Landfill Groundwater Rebound Monitoring Plan (LAI 2010)
- Background Groundwater Monitoring Plan (LAI 2014a)
- Rebound Monitoring Plan Addendum (LAI 2014d).

1.3 Report Organization

This 2018 Annual Report is a consolidation of past annual, biannual, and quarterly reports, which had described different elements of the TLF environmental controls and monitoring facilities. In 2018, the EPA completed its Five-Year Review (FYR) process and organized its review by TLF operable unit (OU5 and OU6). Therefore, this Annual Report is organized as follows:

- Section 2.0: discusses 2018 PCC activities related to the cap, leachate, and condensate systems of OU5 Source Control
- Section 3.0: discusses 2018 PCC activities related to the landfill gas (LFG) collection system of OU5 Source Control
- Section 4.0: discusses 2018 PCC activities related to groundwater monitoring, the dormant groundwater treatment system, and the institutional controls of OU6 Groundwater Remedy
- Section 5.0: summarizes the overall performance and acknowledgements from the EPA's 2018 FYR (EPA 2018b).

[1] Note: the LFG Management Plan was revised in August 2018 (LAI 2018a), reviewed by TPCHD, and was updated in 2019 as a final document (LAI 2019a).

2.0 OU5 SOURCE CONTROL – CAP, LEACHATE, AND CONDENSATE SYSTEMS

The cap system is the primary remedial measure taken to control leachate production at the TLF. The cap system consists of dual membrane, composite, and asphalt caps at the locations shown on Figure 3. The leachate and condensate conveyance system layouts are shown on Figure 4. The condensate collection system extracts and drains condensation from low points in the LFG header piping to prevent restriction of LFG flow; LFG is discussed in Section 3.0. Additional details about how the cap, leachate collection, and condensate collection systems operate, and associated O&M procedures, are provided in the Environmental Operations Plan (LAI 2016b). The Leachate and Condensate Management Plan (LAI 2016c) addresses sampling and reporting procedures.

2018 PCC activities for the three systems generally included the following:

- Cap System:
  - Cap system inspection items (dual membrane, composite liner, and asphalt caps)
  - Asphalt pan lysimeter monitoring
  - Leak detection monitoring
  - Cover survey of settlement monitoring points
  - Emergency cap repairs at Central Area due to subsurface LFG fire
- Leachate Collection System: Sampling
- Condensate Collection System: Sampling.

These activities are discussed in the following sections.

2.1 Cap System

This section summarizes 2018 PCC activities for the cap system. Supporting cap system documentation prepared by the City is included in Appendix A and consists of: 1) cover ponding repair area settlement point survey and biaxial strain calculations, 2) secondary drainage inspection forms, and 3) retaining wall settlement measurements.

2.1.1 Cap System Inspection

The cap system was routinely inspected by qualified SWM staff during 2018 with daily conditions monitoring. The annual inspection was completed on February 19, 2019 by the City project manager[2] during which time the cap system was observed to be in good condition. Cap system inspections are conducted in accordance with the Environmental Operations Plan (LAI 2016b), which includes specific inspection items for the landfill cap (dual membrane, composite liner, and general landfill) and the

[2] Calvin Taylor, licensed hydrogeologist.

asphalt cap. A summary of 2018 inspection observations and maintenance by designated inspection item is provided in Table A-1 in Appendix A (for the landfill cap) and Table A-2 (for the asphalt cap).

Overall in 2018, the landfill cap was observed to be in good condition, performing as intended with some routine maintenance. The cap was repaired near a former LFG extraction well where a subsurface fire occurred, which is discussed in Section 2.1.5. The asphalt cap was observed to be in good condition, performing as intended with some routine maintenance. Material-handling equipment operation caused superficial abrasions and shallow divots in an area of the asphalt cap; re-skinning of the damaged asphalt will occur as needed.

2.1.2 Asphalt Cap Lysimeter Monitoring

The asphalt cap contains one pan lysimeter used to detect leakage of the asphalt cap. The pan lysimeter is monitored from the surface access point shown on Figure 3. The measured volume of liquid found in the lysimeter can be used to calculate the permeability of the asphalt and compare it to the minimum permeability requirement [1×10^{-10} centimeters per second (cm/sec)]. The asphalt cap met the minimum permeability requirement during 2018, and the most recent lysimeter pan reading was 0 milliliters (mL) collected on April 18, 2019. Therefore, the asphalt cap appears to be in good working order with no observable leakage.

2.1.3 Leak Detection Monitoring

With the exception of the Central Area (where the composite cap liner is located), all of the landfill cap areas have a leak detection layer. The leak detection layers are fitted with underdrain pipes that capture water in the leak detection layer and gravity-drain to a catch basin. The underdrain pipes in the catch basin are fitted with a manual valve. Water that may accumulate within the leak detection layer will collect within the underdrain pipes until the valves are opened at the catch basins. Figure 3 shows the location of each of the leak detection catch basins. As shown, the City has designated South Area catch basins, Northeast Area catch basins, Central East Area catch basins, and West Area (meaning combined Northwest Area and Central West Area) catch basins.

The catch basins were inspected monthly by SWM personnel in 2018 to document the presence of liquid in gallons. Observations were consistent with recent years:

- No observable liquid in most catch basins throughout the year.
- Measurable liquid or flowing conditions were observed at two Northeast Area catch basins (#2 and #7; north pipes only) and one West Area catch basin (#4A, both the north and south pipes), generally in the winter and fall.
- The Northeast Area catch basin #2 had the most frequent presence of measurable liquid; measured volumes were minimal, in amounts of 0.25 gallons and 0.5 gallons. Northeast Area catch basin #7 occasionally had measurable liquid amounts of 0.25 gallons.
- When liquid was present, the West Area catch basin #4A was documented as having a light trickle, light flow, steady flow, or heavy flow.

The monthly monitoring data field forms are provided in Appendix B and labeled “Monthly Inspection Report – Secondary Drainage Pipe Volumes.”

2.1.4 Landfill Cover Settlement Monitoring Survey

The City initiated repairs of cap subsidence areas during the fall of 2015 and construction was completed in 2016. After the repairs were completed, the City conducted a survey in 2017 to establish baseline conditions using a ground-based topographic survey. Subsequent surveys were conducted in 2018 and in February 2019 for comparison to the baseline survey to evaluate subsidence using consistent datum, survey intervals, and grid sizes. A survey drawing with survey results for 2017, 2018, and 2019 was prepared by the City and is provided in Appendix A. As shown on the drawing, the comparison in cap elevation monitoring points from year to year indicate that the calculated biaxial strain is less than 1 percent; the maximum allowed cap biaxial strain is 6 percent.

Per the Environmental Operations Manual, surveys are conducted every 5 years, or more often at the SWM engineering staff’s discretion to detect subsidence that may have occurred. Subsidence is not apparent from the 2017 through 2018 monitoring data. Therefore, the City intends to move to a survey frequency of every 5 years for the PCC period and will conduct the next survey in 2023. A final survey will be completed at the termination of the PCC period in accordance with WAC 173-351-500(2).

2.1.5 Central Area Landfill Emergency Cap Repairs

On November 23, 2018, City personnel observed damage and subsidence around LFG extraction well CA11 located in the Central Area of the LFG collection system (Figure 5). Extraction immediately ceased at the well. On November 24, 2018, City personnel observed an open flame at the well indicative of a subsurface fire. City personnel immediately quenched the subsurface fire with potable water. Also, LFG extraction operations in the Central Area were modified to mitigate subsurface fire potential. Subsidence and damage to the landfill cap infrastructure were assessed. Localized subsidence occurred beneath the liner causing a drainage slump, requiring repair of the cap through and beneath the liner to restore cap drainage. The cause of the subsurface fire and subsequent subsidence appears to be due to well CA11 casing construction joint leaks and associated preferential ambient air pathway movement through the liner.

In response to the fire, the City and its contractors prepared and implemented an emergency cap repair, sampling port installation, and well CA11 decommissioning plan scope of work (SOW). Construction to implement the SOW began December 13, 2018 and was substantially complete on December 21, 2018. City personnel coordinated with the permitting agency, TPCHD, throughout the process. Ecology and the EPA were also notified. Documentation pertaining to decommissioning well CA11 was coordinated with Ecology. To mitigate further subsurface fire potential, conservative operational changes are recommended for LFG management and monitoring in the Central Area.

Additional details are provided in the emergency cap repair Construction Completion Report (LAI 2019b).

2.2 Central Area Composite Cap Leachate Collection System

The Central Area leachate collection system consists of two subsystems: the primary leachate collection and removal system and the secondary leachate detection and removal system. The primary system is made up of a drainage layer overlying a high-density polyethylene (HDPE) barrier layer. The secondary system is below the primary system and is virtually identical to the primary system. In addition, a toe drain system exists beneath the Central Area bottom liner to prevent leachate pressure buildup along the sidewall of the Central Area. All leachate collection pipes were constructed with a minimum 2 percent gradient to allow for gravity drainage from south to north. The pipes are constructed of perforated HDPE to allow for collection of the leachate. The toe drain, primary leachate line, and condensate lines (discussed further in Section 2.3) drain into a manhole (i.e., the Leachate Collection Manhole) at the north end of the Central Area. The leak detection pipe drains into a separate manhole (i.e., the Leak Detection Manhole). By isolating the leak detection pipe into its own manhole, inspection of the manhole can quickly confirm if a leak exists. Drainage from the Leachate Collection Manhole and Leak Detection Manhole combine at the Total Effluent Manhole where it is discharged to the sanitary sewer line. These features are shown on Figure 4.

The system is designed to drain via gravity, and thus operates relatively passively. The SWM staff is responsible for inspection, maintenance, and sampling of the system. In 2018, flow rates at the Leachate Collection Manhole were monitored monthly. Flow rates indicate that the total effluent discharge from the Leachate Collection Manhole to the sanitary sewer has been approximately 5 gallons per minute and does not exhibit seasonal variability. A full camera inspection of the leachate collection line is conducted approximately every 5 years and the City plans to conduct an inspection in the 2019/2020 timeframe. Maintenance of the line is performed annually or on an as-needed basis.

2.3 Condensate Collection System

The condensate collection system is divided into four collection areas, each with a condensate tank, vacuum pump, and condensate pump. The four areas, West (M4), North, South, and Main (east), are manually operated and monitored by SWM staff. Each area contains a small structure, either a shed or in the south area, a vault, that houses the pumps and valves. The condensate is extracted through a counter vacuum system. The vacuum pump located within the structure applies a suction force on the LFG manifold system that counters the vacuum applied by the LFG blowers. The pressure differential allows the vacuum valve stations to drain the condensate from the LFG manifold and into the condensate manifold. Condensate that is drained from the vacuum valve stations enters the condensate manifold where gravity and the condensate pumps convey the condensate to the collection tanks.

When the tanks in the four areas reach capacity, the SWM staff use the condensate pumps to convey the condensate to the former[3] pH dosing chamber. The former pH dosing chamber serves as a central condensate storage tank where condensate is gravity-drained into the sanitary sewer via a 2-inch HDPE line to the Leachate Collection Manhole. These features are shown on Figure 4.

The condensate collection system is manually operated; the LFG extraction system is constantly under vacuum pressure and operates 24 hours a day, 7 days a week. The counter suction condensate collection system is manually turned on when needed as determined by the SWM staff; this occurs about once a week but could be modified depending on the system needs. System inspection is ongoing for the condensate collection system. Operation of the system in 2018 was normal.

2.4 Leachate, Condensate, and Leak Detection System Sampling

Leachate sampling is conducted for the toe drain, the Central Area leachate collection line, and combined effluent at the Leachate Collection Manhole. The combined effluent discharge at the Leachate Collection Manhole is the combination of the toe drain, Central Area leachate collection line, and condensate discharge. The leak detection discharge is sampled in the Leak Detection Manhole. The toe drain is shown as a dashed dark blue line on Figure 4. The other leachate or combined effluent features described above are shown in pink on Figure 4.

Condensate sampling occurs at four locations: North Condensate Building Collection Tank, South Condensate Collection Tank, Main Condensate Building and Collection Tank, and West (M4) Condensate Building and Collection Tank. Condensate conveyance lines to the condensate building/tank locations are show in green on Figure 4. The condensate sampling locations (the condensate building/tank locations) and discharge lines to a pH dosing chamber are shown in turquoise blue on Figure 4. All leachate, condensate, and leak detection drainage is discharged to the onsite sanitary sewer system.

Leachate and/or condensate is sampled regularly for four analyte groups: Conventionals, metals, volatile organic compounds (VOCs), and semivolatile organic compounds (SVOCs). The analyte groups are based on how the data are grouped in the City database:

- Conventionals
    - Ammonia, biological oxygen demand, chemical oxygen demand, total suspended solids, petroleum hydrocarbons–silica gel cleanup/hexane extractable material, hexavalent chromium, total cyanide, and free cyanide
- Metals
    - Group 1: Arsenic, cadmium, chromium, copper, lead, mercury, nickel, selenium, silver, and zinc
    - Group 2: Antimony, beryllium, molybdenum, thallium, and tin

[3] Per the Leachate and Condensate Management Plan (LAI 2016b), pH adjustment is no longer required.

- VOCs (EPA Method 624; 37 analytes)
- SVOCs (EPA Method 625; 67 analytes).

Selected conventional and metal analytes have pre-treatment standards related to discharge to the sanitary sewer system.

In 2018, sampling was conducted on August 29 and 30, and September 4 and 5. Samples were collected in accordance with the Leachate and Condensate Management Plan (LAI 2016c) and laboratory analytical results are provided in Table C-1 of Appendix C. Conventional and metal analytes with pre-treatment standards were either not detected or detected at concentrations below applicable pre-treatment standards. Low-level concentrations of VOCs tetrachloroethene (PCE; 0.64 micrograms per liter [µg/L]), trichloroethene (TCE; 0.12 µg/L), and vinyl chloride (0.84 µg/L) were detected in the "South Condensate" sample collected on August 29, 2018. Low-level TCE (1.36 µg/L) and vinyl chloride (0.29 µg/L) concentrations were also detected in the "Main Condensate" sample collected on August 29, 2018. Benzene, toluene, ethylbenzene, and xylenes, and related VOC constituents were frequently detected at most leachate and condensate sampling locations. Most SVOCs were not detected.

3.0 OU5 SOURCE CONTROL – GAS COLLECTION AND CONTROL SYSTEM

The primary objective of the gas collection and control system (GCCS) is to prevent migration or uncontrolled release of LFG from the facility, by collecting it in the subsurface and providing treatment prior to controlled release to the atmosphere. Chapter 173-351 WAC, Criteria for Municipal Solid Waste Landfill, provide threshold requirements to show proper controls are maintained by mandating that methane concentrations not exceed the lower explosive limit (LEL) of 5 percent methane by volume at the property boundary of a landfill. Chapter 173-351 WAC further provides maximum allowable methane concentration for both onsite and offsite structures: methane must not exceed 100 parts per million in offsite structures, or 0.25 percent methane in onsite structures. Compliance with the regulatory limits is confirmed through monitoring at the system of LFG monitoring probes installed at the perimeter of the landfill.

LFG generated during decomposition of landfill waste is extracted by the GCCS via a series of vertical and horizontal extraction wells that operate under a vacuum. The LFG is conveyed from these points of extraction under vacuum and routed to the blower/flare system, which provides LFG treatment via controlled oxidation (flaring). The GCCS operates 24 hours per day throughout the year. The approximate locations of operating GCCS extraction wells, horizontal collectors, and header piping (both exposed and buried) are shown on Figure 5.

The LFG compliance monitoring network was designed to detect LFG migration beyond the TLF property and monitor the effectiveness of the GCCS, and is shown on Figure 5. The network of monitoring probes includes 84 probes located at the typical point of compliance (POC; i.e., the property boundary), and some located off site. In addition to the 84 monitoring probes, the monitoring network also includes former perimeter extraction wells (PW10, PW11, PW12, PW14, PW15, and PW17) that were converted from extraction wells to probe monitoring stations to provide additional perimeter monitoring when some offsite probes were decommissioned in 2016 (LAI 2016a). Some probes are located slightly outside of the TLF property. The Home Depot (HD) and Central West (CW) probes are located north of the TLF on Home Depot property, as shown on Figure 5. Detailed depictions of probe stations by landfill area are shown on Figure 7 (Northeast), Figure 8 (Northwest), Figure 9 (Central East), Figure 10 (Central Area), Figure 11 (Central West), and Figure 12 (South).

Additional details about the GCCS are provided in the Landfill Gas Management Plan (LFG Management Plan; LAI 2017a, 2018a). The LFG Management Plan document is a required element of the CD (Section 3.5.6 of the CD Scope of Work; DOJ 1991). In addition to CD requirements, the GCCS must operate in accordance with the current TPCHD Solid Waste Permit and with requirements in WAC 173-351-200: Operating Criteria and WAC 173-351-500: Closure and Post-Closure Care of the State Criteria for Municipal Solid Waste Landfills.

2018-related O&M activities for the GCCS included the following:

- Revisions to the LFG Management Plan (LAI 2018a)
- LFG database development
- Routine LFG extraction well operational monitoring
- Routine LFG compliance monitoring
- Installation of a sampling port within Central Area emergency cap repair area.

These activities are discussed in the following sections.

3.1 Landfill Gas Management Plan Update

On August 10, 2018, the City submitted a revised 2018 Post-Closure Landfill Gas Management Plan (LAI 2018a) to TPCHD. On October 16, 2018, TPCHD provided comments (Bosch 2018). In addition to updating the LFG Management Plan to incorporate TPCHD's October 2018 comments, the document warranted further edits after the subsurface fire and cap repairs discussed in Section 2.1.5. Revisions to the document are being completed in 2019.

3.2 Landfill Gas Database Development

The City worked throughout 2018 to develop a database to store LFG monitoring data, and to create a web-based user interface for the SWM operators and TLF managers to view pertinent LFG data in real-time. The database will be operational in 2019 for input and output of all 2018 and 2019 extraction well data. Later in 2019, the City plans to incorporate input and output of perimeter LFG monitoring data.

3.3 Landfill Gas Extraction Operations Monitoring

One-hundred and sixty-five (165) operating LFG extraction wells were monitored in 2018 per the LFG Management Plan procedures applicable during 2018 (LAI 2017a) and at the frequency shown in Table 1. LFG monitoring was conducted quarterly at most of the 165 extraction wells; some were measured less frequently than quarterly. Routine LFG monitoring at extraction wells includes evaluating the following gas composition and flow parameters:

- Methane concentration (percent by volume)
- Carbon dioxide concentration (percent by volume)
- Oxygen concentration (percent by volume)
- Balance gas concentration (effectively nitrogen; percent by volume)
- Pressure (inches-water column [WC; positive or negative])
- Flow velocity (feet per minute [ft/min]).
- LFG wellhead temperature (degrees Fahrenheit).

In addition to the above-noted parameters, SWM operators record observations of unusual wellhead or valve conditions, odors, valve positioning, modifications to flow or pressure caused by valve adjustments, and visual observations of needed maintenance or repairs.

After measuring and evaluating the parameters listed above, SWM operators may modify flow at any extraction well location by adjusting the wellhead valves. In general, the valves are opened further at locations exhibiting higher concentrations of methane, and turned down at locations that do not exhibit high concentrations of methane. At TLF, the target methane concentration is 35 percent, which is used as a general guideline for these adjustments—flow is increased when concentrations are consistently greater than 35 percent. There are exceptions to this general guideline to allow for operator discretion and to reduce the chances of extracting at a flow rate too high for a given location. If extraction flow rates are too high with respect to LFG production from the immediate subsurface waste, excess flow is often made-up by surface or lateral intrusion, which can introduce oxygen (increasing the risk of subsurface fire) and dilute the concentration of methane in the extracted gas (impairing function of the LFG flare). Additional details regarding the approach to GCCS operations are provided in the LFG Management Plan (LAI 2017a).

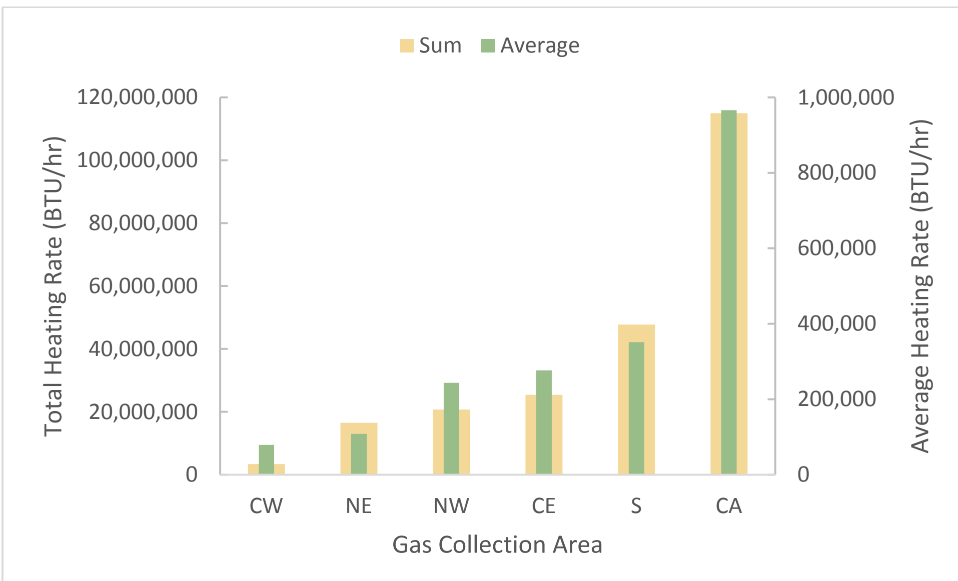
As indicated, methane is the primary component of LFG used at the TLF to evaluate GCCS effectiveness, although other monitored gases provide additional information regarding waste decomposition, air intrusion, or risks for subsurface fire. To demonstrate typical spatial distribution of methane concentrations throughout the TLF, third quarter 2018 methane concentrations are shown on Figure 13. A total of 641 methane measurements were collected from extraction wells in 2018. To evaluate methane by percent volume concentrations, measurements are grouped by color-coded ranges of 0 to 5 percent, 5 to 15 percent, 15 to 35 percent, 35 to 55 percent, and 55 percent+ in Table C-1 in Appendix C, which is consistent with methane concentrations shown on Figure 13. The total number of methane concentration measurements and overall percentages by range (and associated colors shown on Figure 13) are as follows:

% by Vol.	Totals	% of Total
0-5	101	15.8%
5-15	55	8.6%
15-35	304	47.4%
35-55	167	26.1%
55+	14	2.2%
Total:	641	100.0%

Consistent with Figure 13, the above-noted percentages indicate nearly half of all methane measurements are in the 15 to 35 percent range and more than a quarter are in the 35 to 55 percent range. These data demonstrate SWM operator efforts to keep methane concentrations near the target guidance values of 35 percent.

To accurately assess where methane production is occurring, methane concentration measurements and their co-collected flow velocity measurements should be evaluated together.[4] Heating rates can be calculated to assess methane production using methane concentration measurements, flow velocity measurements, and the standard heating value of methane in British thermal units per hour (BTU/hr). Calculated heating rates allow for a more complete assessment of GCCS operating efficiency than merely observing methane concentrations. With an understanding of calculated heating rates and operating efficiency, the SWM operator has further indication of where to focus extraction efforts. The 2018 monitoring data measurements for operating extraction wells and calculations of heating rates are included in Appendix C (Table C-1[5]). From Table C-1 calculated heating rates, eight out of the top 10 methane-producing extraction wells are from the Central Area (HZW 06, CA 15, CA 29a, CA 11, HZW 09, CA 24, CA 28b, and CA 08b), and two are from the South Area (S 02a and S 19b). Central Area extraction wells CA 15 and HZW 06 are often the greatest methane producers. To demonstrate spatial distribution of calculated heating rates throughout the TLF, third quarter 2018 heating rates are shown on Figure 14.

The chart below further illustrates heating rates by area:



The above graph provides the total heating rate and average heating rate per TLF area for 2018. The graph provides abbreviations for the gas collection areas as follows: Central (CA), South (S), Central East (CE), Northwest (NW), Northeast (NE), and Central West (CW). As shown in the above graph, the greatest total and average heating rates occur in the Central Area, followed by the South Area, then rates drop off. The Central Area appears twice as productive as the South Area. The Central East Area

[4] Some extraction wells have low flow velocities and technically produce a relatively low amount of methane, even though methane concentrations are high.

[5] Data provided by the City and were exported from its LFG data base.

and Northwest Area appear relatively similar to one another. The Northeast Area has relatively low production and the Central West Area shows the lowest production. From Figure 2, relative ages of the fill sites situated within the gas collection areas (Figure 5) appear to indicate[6] that the Central Area is the youngest, the Central West Area is the oldest with the Northeast Area being the second oldest, and the other three areas (South, Central East, and Northwest) have a mix of waste from the 1970s with late 1980s or early 1990s waste. Given the data shown on the graph and the relative ages of the waste fillings associated with the gas collection areas, it is logical that the Central Area is the highest producer of methane, the Central West Area is the lowest producer, and suggests that the methane production capacity at the Central East Area and Northwest Area may be further optimized with a potential to increase methane production/heating rates closer to rates achieved in the South Area.

3.4 Probe Compliance Monitoring

State requirements under Chapter 173-351 WAC, Criteria for Municipal Solid Waste Landfill, mandate that methane concentrations not exceed the LEL of 5 percent by volume at the landfill property boundary. Compliance monitoring has shown that the perimeter of the TLS is well-protected by operation of the GCCS; only infrequent traces of methane—well below the allowable threshold of 5 percent by volume—have been observed in recent years.

Compliance monitoring locations include 76 “PS” probe stations, six “HD” probe stations (HD and HDA, and HD1 through HD4), and two Northeast Area monitoring locations designated as CW and Sewer. The PS probe stations are located throughout the landfill areas as shown on Figures 7 through 12. The HD probe stations and locations CW and Sewer are in the Northeast Area, as shown on Figure 7. All 2018 probe compliance monitoring field forms from the City are provided in Appendix C. Minimum compliance monitoring frequency by location or area is detailed in Table 1.

The 2018 compliance monitoring was conducted weekly at all 76 PS probe stations, HD1 through HD4, CW, and Sewer probe stations, and daily at HD and HDA probe stations. During the latter part of 2018, monitoring was adjusted to biweekly. Each probe station monitors one to five subsurface monitoring zones with separate completions placed in a single boring. Probe depth is designated by color. The designations are, from shallowest to deepest: red, orange, yellow, blue, and white.

The PS, CW, and Sewer probe station data were typically collected on the same day and are combined as one set of field forms in Appendix C. From the field forms, it appears that the only detection of methane in 2018 from the PS, CW, and Sewer locations was at PS #28 on January 9, 2018. PS #28 is located in the Northwest Area (Figure 8). The detections were below 5 percent by volume with the shallowest two zones at 3 percent by volume (red and orange) and the three subsequent deeper zones at 4 percent by volume (yellow, blue, and white). Daily follow-up monitoring indicated that

[6] Assessment based on highest filling date range for the respective “gas collection area.”

methane returned to zero at these locations without requiring system modification, and the detections were likely the result of barometric pressure changes.

The HD probe station is located off site in the Home Depot parking lot, as shown on Figure 8. Consistent with monitoring in previous years, the HD probe station often demonstrated subsurface methane concentrations greater than 5 percent by volume throughout much of 2018. As previously demonstrated in the North End Landfill Gas Control Evaluation (LAI 2014b) and discussed in the 2018 LFG Management Plan (LAI 2018a), methane detections at this offsite location (HD) do not appear related to the TLF. This conclusion is supported by 2018 monitoring conducted between the TLF and the HD probe station discussed in the following paragraph. In the coming years, it is anticipated the City will cease monitoring at this offsite location because the methane detection appears unrelated to the TLF.

Probe station HD-A[7] is on the boundary between the TLF and the Home Depot property. Probe stations HD1 through HD4 (or HD01 and HD04 as shown on Figure 8) are located within the TLF and are oriented in a transect that parallels the property boundary with Home Depot. From the field forms, methane concentrations were not detected at HDA in 2018 and were detected infrequently at HD1 through HD4. HD1 had four methane detections in 2018 ranging from 2 to 6 percent by volume; all were within the “yellow” zone depth interval. HD2 had four methane detections in 2018 with values of 1 or 2 percent by volume, typically occurring in the orange zone and one time in the red zone. HD3 had one methane detection at 3 percent by volume in the orange zone. HD4 had three methane detections ranging from 2 to 7 percent by volume occurring in the red and blue zones. In summary, of these onsite probe stations, two locations (HD1 and HD4) each had a methane concentration that exceeded 5 percent by volume one time in 2018; however, HDA had no detections and is on the property boundary.

3.5 Landfill Gas Sampling Port Installation

As discussed in Section 2.1.5, a sampling port was installed during emergency cap repairs after the subsurface fire and well CA11 decommissioning. The sampling port is a 4-inch polyvinyl chloride (PVC) LFG sampling port with a 1-ft perforated section keyed into the waste, with a solid PVC casing from the top of the waste to the ground surface. The sampling port was installed to monitor carbon monoxide, temperature, and pressure regularly, which will be used to assess if replacement of well CA11 is warranted in the cap repair area. In addition, should observations indicate the likely potential for subsurface fire, water can be added at the sampling port. The sampling port is located within approximately 25 feet of decommissioned well CA11 (shown on Figure 10).

[7] Field form shows HDA although it is HD-A, as shown on Figure 8.

4.0 OU6 GROUNDWATER REMEDY

The ROD-prescribed final site remedy included a groundwater extraction and treatment system (GETS; constructed in 1992), groundwater performance standards (GWPS), surface water standards, and the point of compliance (POC) as the landfill boundary, which fall under OU6. Contaminants of concern (COCs) in site groundwater have historically included VOCs, SVOCs, and heavy metals. The goal of the GETS was to remediate groundwater at the POC and within the existing contaminant plume to the groundwater performance standards. Specifically, the GETS was implemented to extract and treat groundwater contamination flowing from the western boundary of the TLF toward Leach Creek. Landfill capping source controls (OU5), the GETS system, and other mass removal processes such as degradation and gas extraction by the GCCS (OU5) have collectively remedied impacts to groundwater related to the TLF.

Several wells (monitoring and some extraction) have been decommissioned over the years as shown on Figure 6. The remaining environmental controls and monitoring facilities for OU6 consist of the semi-dormant GETS,[8] the GETS outfall surface water compliance monitoring location, a reduced groundwater monitoring well network, and institutional controls. The City is implementing post-closure surface water compliance and groundwater monitoring, as required by the EPA via the CD (Appendix II, SOW; DOJ 1991), and compliance with its TPCHD permit per WAC 173-351-500 (Closure and Post-Closure Care).

2018 groundwater and surface water monitoring was conducted in accordance with plans specified in Section 1.2 (LAI 2014a, c, d, 2017b). 2018 OU6-related activities included the following:

- Well decommissioning
- Groundwater and surface water monitoring
- Supplemental studies related to groundwater monitoring including a rebound monitoring plan discontinuation evaluation and a soil vapor investigation
- Operation of the five operating GETS extraction wells
- Institutional controls.

These activities are discussed in the following sections.

4.1 Well Decommissioning

In 2018, two monitoring well locations (TL-08a and well cluster TL-08b, c), two extraction wells (W-09 and W-36), and the Landfill Augmentation Well were decommissioned (Figure 6). In December 2017, the City proposed to decommission monitoring well TL-08a, well cluster TL-08b,c, W-09, and the

[8] After 1998, GETS influent groundwater no longer required treatment because GETS influent concentrations had decreased below performance standards identified in the CD for discharge to the sanitary sewer (LAI 2016d). By August 2002, GETS influent met ROD performance standards for discharge to surface water. Since 2003, untreated GETS effluent discharges at the GETS Outfall to Leach Creek.

Landfill Augmentation Well (LAI 2017c), and received EPA approval to decommission all except for the Landfill Augmentation Well (EPA 2018c). Wells TL-08a, well cluster TL-08b,c, and W-09 were decommissioned during the week of January 30 through February 2, 2018, as reported in the February 20, 2018 notification letter (LAI 2018c).

In the February 2018 letter, the City provided additional rationale for decommissioning the Landfill Augmentation Well plus extraction well W-36, and communicated its intent to proceed unless the agencies (EPA, TPCHD, and Ecology) had any objections. The EPA provided an email response (Jennings 2018a) to the February letter approving decommissioning of W-36. W-36 and the Landfill Augmentation Well were decommissioned by Cascade Drilling using perforation and grouting on March 21, 2018 and April 12, 2018, respectively.

4.2 2018 Groundwater and Surface Water Monitoring

In 2018, the City conducted groundwater monitoring at 29 wells and surface water monitoring at the GETS outfall (Figure 6). The 2018 Post-Closure groundwater monitoring well network included two background wells (offsite and upgradient of the TLF to the east), seven point of compliance (POC) wells (along the TLF's western, downgradient boundary), and nine downgradient wells (offsite between the western TLF boundary and Leach Creek). The City sampled 11 rebound monitoring well locations in 2018. All wells were sampled on a quarterly basis with the exception of W-36, which was decommissioned in March 2018. Details about the 2018 groundwater and surface water monitoring locations are provided in Table 2.

4.2.1 Groundwater Levels

There is a single aquifer unit in the vicinity of the TLF consisting of relatively permeable quaternary Vashon advance outwash (Qva) and quaternary pre-Olympia gravel (Qog) deposits. The underlying pre-Olympia lacustrine (Qol) silt is an aquitard that represents the base of this unit. Groundwater flow beneath the TLF is recharged from the Fircrest Upland north of the landfill and the South Tacoma Channel east of the landfill. In general, regional groundwater flows from the recharge areas north and east of the TLF and discharges to Leach Creek west of the landfill. Regional groundwater flow from the north and to the Tacoma Channel are documented in past records prepared when the monitoring well network was more extensive (EPA 1988; LAI 2016d).

2018 water level measurements were collected at all 29 groundwater sampling locations prior to sampling. Groundwater elevations are generally similar from year to year; however, resulting contours may differ based on the number of wells measured, which depends on the sampling plan followed.

Groundwater elevation contours for 2018 are presented in Figure 15. The 2018 monitoring well network primarily consisted of wells along the western boundary of the landfill and off site to the west between the landfill boundary and Leach Creek. From Figure 15, the groundwater gradient appears relatively flat beneath the landfill boundary due to OU5 capping and surface drainage controls, which prevent recharge. Localized cones of depression are apparent at or near active extraction wells (W-16, W-15, W-04 and W-03R). The groundwater gradient west of the landfill boundary is from east to west toward Leach Creek.

4.2.2 Analytical and Quality Assurance/Quality Control Methods

Post-closure groundwater monitoring wells and rebound monitoring wells have the same performance standards and are sampled for the same constituents. The analytical requirements are grouped into two categories: COCs for which there are performance criteria based on potential risk to human or ecological receptors; and landfill indicator parameters useful for monitoring the continued performance of the GETS. GWPS are presented in Table 3.

Samples were analyzed as outlined in the SAP (LAI 2017b). Groundwater samples were analyzed by the City's laboratory for 9 COCs consisting of VOCs, 17 landfill indicator parameters consisting of metals, and 7 other field/laboratory parameters. GETS Outfall surface water samples were analyzed for the 9 groundwater COCs as well as iron, manganese, and field parameters. 2018 groundwater analytical results are tabulated in Appendix D.

COCs were reported to the Minimum Project Report Limit. Some COC concentrations may be reported to the Method Detection Limit (MDL) to meet the Minimum Project Report Limit. In these cases, values are qualified as estimated (J) between the MDL and Practical Quantitation Limit (PQL) as they are not as accurate as values reported greater than the PQL (the low standard or 3 to 5 times the MDL). The data validation reports follow the most current EPA Contract Laboratory Program National Functional Guidelines for Data Review (EPA 2016a, b). Validation reports were archived with the complete data validation packages and are available from the City for review upon request.

4.2.3 Groundwater Quality Data Results and Discussion

2018 COC results by well are presented in Table 4 with GWPS, maximum detections, number of detections, and number of samples collected. Exceedances of GWPSs occurred only at wells TL-11A and TL-26A. 2018 groundwater VOC results for all other monitoring wells were either non-detect or detected at concentrations well below the GWPS.

At well TL-11A, the PCE and TCE performance standard of 5 μg/L was exceeded during all four quarters of 2018 with concentrations ranging 5.2 to 5.9 μg/L (PCE) and 9.5 to 10 μg/L (TCE). At well TL-26A, the TCE performance standard was exceeded during the first quarter (only) at a concentration of 5.1 μg/L. Well TL-11A is located along the TLF boundary at the southwest corner, and well TL-26A is west to northwest of TL-11A off site (Figure 15). PCE and TCE concentration time series plots for TL-11A and TL-26A are provided as Figure 16 and Figure 17, respectively, which show that recent concentrations have been relatively stable and close to the GWPSs.

Consistent with past quarterly and annual groundwater reports, the City has provided statistical analyses for COC groundwater monitoring data using Sanitas® 9.3 for Groundwater (Sanitas). The two analyses conducted are Sen's Slope/Mann-Kendall and confidence intervals.

Although GWPSs drive groundwater monitoring at the site, Sanitas uses early warning values as screening triggers for statistical analysis of COCs. For 2018 data, Sanitas included the early warning value exceedances summarized in Table 5 for statistical analyses. For Sen's Slope/Mann-Kendall, Sanitas found no significant trends. For the confidence interval statistical analysis (done per quarter), Sanitas identified which early warning value exceedances also exceeded GWPS. Only concentrations at two wells met this criteria, TL-11A and TL-26A (consistent with the discussion above). The Sanitas Sen's Slope Estimator graphs and tables, the summary Sen's Slope/Mann-Kendall table, and quarterly confidence interval plots and tables are provided in Appendix E.

4.2.4 Surface Water Monitoring and Data Results

In 2018, the City conducted surface water monitoring at the GETS outfall on a quarterly basis (February, May, August, and November/December[9]). The GETS outfall is located near the headwaters of Leach Creek (Figure 6) where two culverts (42-inch and 36-inch-diameter) discharge to the Leach Creek holding basin. The GETS outfall was sampled from the northernmost culvert as a grab sample and analyzed for groundwater COCs as well as iron, manganese, and field parameters. GETS outfall sampling details are provided in Table 2 and sampling results are provided in Table 6.

GETS outfall surface water results for VOCs were compared to the GWPSs defined in Table 8 of the ROD (EPA 1988); all VOC concentrations were below their respective detection limits in 2018. GETS outfall surface water results for metals iron and manganese were compared to surface water discharge limits (1,500 µg/L and 1,900 µg/L, respectively), which were established under the CD. The sampling results show iron and manganese were below discharge limits during all four quarters.

4.3 Supporting Groundwater Monitoring Studies

LAI conducted an assessment regarding the discontinuation of rebound monitoring on behalf of the City in 2018 using the City's quarterly groundwater data through 2018, and continued into 2019. The results of the assessment support updating governing groundwater monitoring plans (LAI 2014a, c, d, 2017b) into a consolidated plan with refined monitoring program details and decommissioning additional wells where appropriate; these activities will be coordinated with the EPA in 2019.

In 2018, the EPA prepared the Optimization Review Report (EPA Optimization Report; EPA 2018b) as a part of the 5th 5-Year Review of the TLF. The EPA Optimization Report included "recommendation 5.1," which proposed soil vapor sampling at existing extraction wells near the southwest corner of the TLF by well TL-11A to characterize the source of residual VOC groundwater plumes in the area. In

[9] The City sampled for VOCs on November 30th and for iron/manganese on December 11th.

response to the EPA Optimization Report, LAI prepared and submitted the Soil Vapor Investigation Work Plan (LAI 2018b) for EPA approval; the EPA subsequently approved the work plan via email (Jennings 2018b). The soil vapor investigation was implemented by LAI for the City on October 30 and 31, 2018. Soil vapor was sampled at 32 locations (LFG extraction wells and probe stations) throughout the project area at the locations shown on Figure 18. Samples were analyzed for PCE and TCE and laboratory analytical results are provided in Table 7. A technical memorandum with results from the investigation was initiated in 2018 and completed in 2019 (LAI 2019c). The technical memorandum included recommendations pertaining to soil vapor extraction (i.e., LFG extraction) operational changes in the area near TL-11A and supporting soil vapor monitoring. Additional details are provided in the technical memorandum.

4.4 Groundwater Extraction and Treatment System Operations

The goal of the GETS was to remediate groundwater at the POC and within the existing plume to drinking water standards or health-based criteria specified in the CD. The need to treat GETS influent ceased after 1998, and untreated GETS influent has been discharging at the GETS Outfall to Leach Creek since 2003 (LAI 2016d). The 2018 GETS outfall results were discussed in Section 4.2.1.

The GETS originally included 36 extraction wells. In 2009, the City petitioned the EPA to turn off the 14 offsite GETS wells (W-30 through W-43) and its petition was accepted. In December 2009, the City petitioned the EPA to turn off 17 POC extraction wells and retain five (W-01, W-02, W-04, W-15, and W-16). In a letter dated February 11, 2010, the EPA accepted the City's request with conditions (EPA 2010). A primary condition of the EPA's approval for shutting down the 17 POC extraction wells was preparation of the Tacoma Landfill Groundwater Rebound Monitoring Plan (LAI 2010) where the rationale for retaining the five POC extraction wells was detailed. The 17 POC extraction wells were shut down on March 17, 2010, leaving W-01, W-02, W-04, W-15, and W-16 in operation.

Rebound monitoring at the TLF has been conducted quarterly since the 2nd quarter of 2010 and all five of the operating extraction wells have been on and off on occasion for maintenance. Extraction well W-02 was shut down in February 2014 due to sanding attributed to a damaged well screen and was replaced with well W-03R, which was installed in 2015 as documented in the PCC Plan (LAI 2016d). Currently, the five extraction wells in operation are W-01, W-03R, W-04, W-15, and W-16 and their estimated pumping rates[10] from January 2018 were between 6.5 and 47.3 gallons per minute. The location of GETS extraction wells are shown on Figure 6.

4.5 Institutional Controls

Residential and commercial properties located around remaining groundwater contamination are connected to the public water supplies. Water supply wells installed prior to implementation of the institutional controls (ICs) are not used for drinking water and there is one remaining residential well

[10] Provided by a SWM operator.

that is sampled (EPA 2018a). The ICs remain in effect and are documented in the Tacoma Landfill Institutional Controls Plan (City of Tacoma 2012).

5.0 CONCLUSIONS AND RECOMMENDATIONS

The following sections present conclusions and recommendations for OU5 and OU6 based on 2018 activities, and for eventual delisting of the TLF as a continued discussion from the EPA's 2018 Optimization Report (EPA 2018b).

5.1 OU5 Source Control – Cap, Leachate, and Condensate Systems

The cap, leachate, and condensate systems operated as designed in 2018 with routine maintenance. Due to a LFG collection system-related subsurface fire at former extraction well CA11, part of the Central Area cap was reconstructed around CA11 with a new sampling port installed to allow for LFG monitoring and to provide a conduit for applying water to the subsurface as-needed.

The landfill cover settlement monitoring survey results initiated following 2016 cap subsidence repairs indicate significant subsidence is no longer occurring. Therefore, in accordance with the Environmental Operations Manual, surveys will be conducted every 5 years starting after 2018. Therefore, the next settlement survey will be conducted in 2023. A final survey will be completed at the termination of the PCC period in accordance with WAC 173-351-500(2).

5.2 OU5 Source Control – Landfill Gas Collection System

With the exception of the subsurface fire at former extraction well CA11, routine operation and maintenance activities for the LFG collection system occurred in 2018. An assessment of 2018 methane concentrations and flow velocity data yielded heating rates that identify where 2018 methane production occurred optimally, where it could likely be increased, and where methane production will likely remain low due to the age of subsurface waste. Given the 2018 subsurface fire incident and identification of methane production optimization opportunities, it is recommended that the City increase LFG monitoring to mitigate subsurface fires and optimize methane production. The revised 2019 LFG Management Plan (LAI 2019a) should be implemented immediately upon approval from TPCHD. In addition, LFG system operational changes will be proposed in 2019 as they pertain to remediating soil vapor near groundwater monitoring well TL-11A to improve groundwater conditions.

5.3 OU6 Groundwater Remedy

The GETS operation is minimal with five operating groundwater extraction wells with a combined untreated effluent discharge below applicable performance standards. The groundwater monitoring well network has been reduced and there is opportunity to continue to reduce the network (i.e., well decommissioning) to focus on post-closure compliance and to continue to monitor groundwater impacts near well TL-11A. As indicated, operational changes to the LFG system near TL-11A will be proposed for implementation in 2019 with supporting soil vapor monitoring to remediate localized PCE and TCE impacts in groundwater. In addition, it is recommended that the governing groundwater monitoring plans (LAI 2014a, c, d, 2017b) be consolidated into one refined monitoring plan that supports post-closure compliance monitoring and remediation performance monitoring near TL-11A.

5.4 Tacoma Landfill Delisting Strategy

The TLF operates under a TPCHD permit and existing environmental controls, and monitoring facilities are in place for PCC. The EPA's 2018 Optimization Report recommends exploring exit strategies for delisting the TLF site from the NPL and options for transferring regulatory oversight to a more appropriate framework (EPA 2018b). Per the EPA, "with attainment of all ROD COCs demonstrated and the groundwater remedy closed, the conditions at the (TLF site) would be no be different than those of a typical Resource Conservation and Recovery Act (RCRA) Subtitle D landfill. As such, adequate oversight could likely be provided by the (TPCHD) and Ecology without the involvement of EPA" (EPA 2018b).

Current post-closure monitoring has largely demonstrated attainment of ROD COCs throughout the TLF with the exception of groundwater performance standard exceedances of PCE and TCE primarily at well TL-11A (Figure 16). The EPA encourages[11] the City to use its Guidance for Evaluating Completion of Groundwater Restoration Remedial Actions (EPA 2013), which has two phases of groundwater monitoring:

- Remediation monitoring phase
- Attainment monitoring phase.

As recommended by the EPA,[12] the City investigated soil vapor near TL-11A in October 2018 and intends to implement soil vapor extraction as active remediation near TL-11A in 2019 with a vapor monitoring plan. Once PCE and TCE concentrations at TL-11A decline and remain below GWPS, groundwater monitoring locations will transition from remediation monitoring to attainment monitoring. Once attainment of all ROD COCs is demonstrated, the EPA indicates the City would be able to close the groundwater remedy (EPA 2018b).

Beyond the immediate TL-11A location, EPA recommends[13] the LFG system be monitored for COCs to demonstrate that the very low or undetectable concentrations of COCs have been the result of mass removal rather than isolation by the cap system component of OU5. Separate from the 2019 LFG management plan (LAI 2019a), the City will propose an approach to demonstrate COC mass removal has been effective at the TLF.

[11] Section 5.2 of the Optimization Report (EPA 2018b).

[12] Section 5.1 of the Optimization Report (EPA 2018b).

[13] Section 5.4 of the Optimization Report (EPA 2018)b.

6.0 USE OF THIS REPORT

This 2018 annual report has been prepared for the exclusive use of the City of Tacoma, Washington and regulatory agencies) for specific application to the Tacoma Landfill project. No other party is entitled to rely on the information, conclusions, and recommendations included in this document without the express written consent of LAI. Further, the reuse of information, conclusions, and recommendations provided herein for extensions of the project or for any other project, without review and authorization by LAI, shall be at the user's sole risk. LAI warrants that within the limitations of scope, schedule, and budget, our services have been provided in a manner consistent with that level of care and skill ordinarily exercised by members of the profession currently practicing in the same locality under similar conditions as this project. We make no other warranty, either express or implied.

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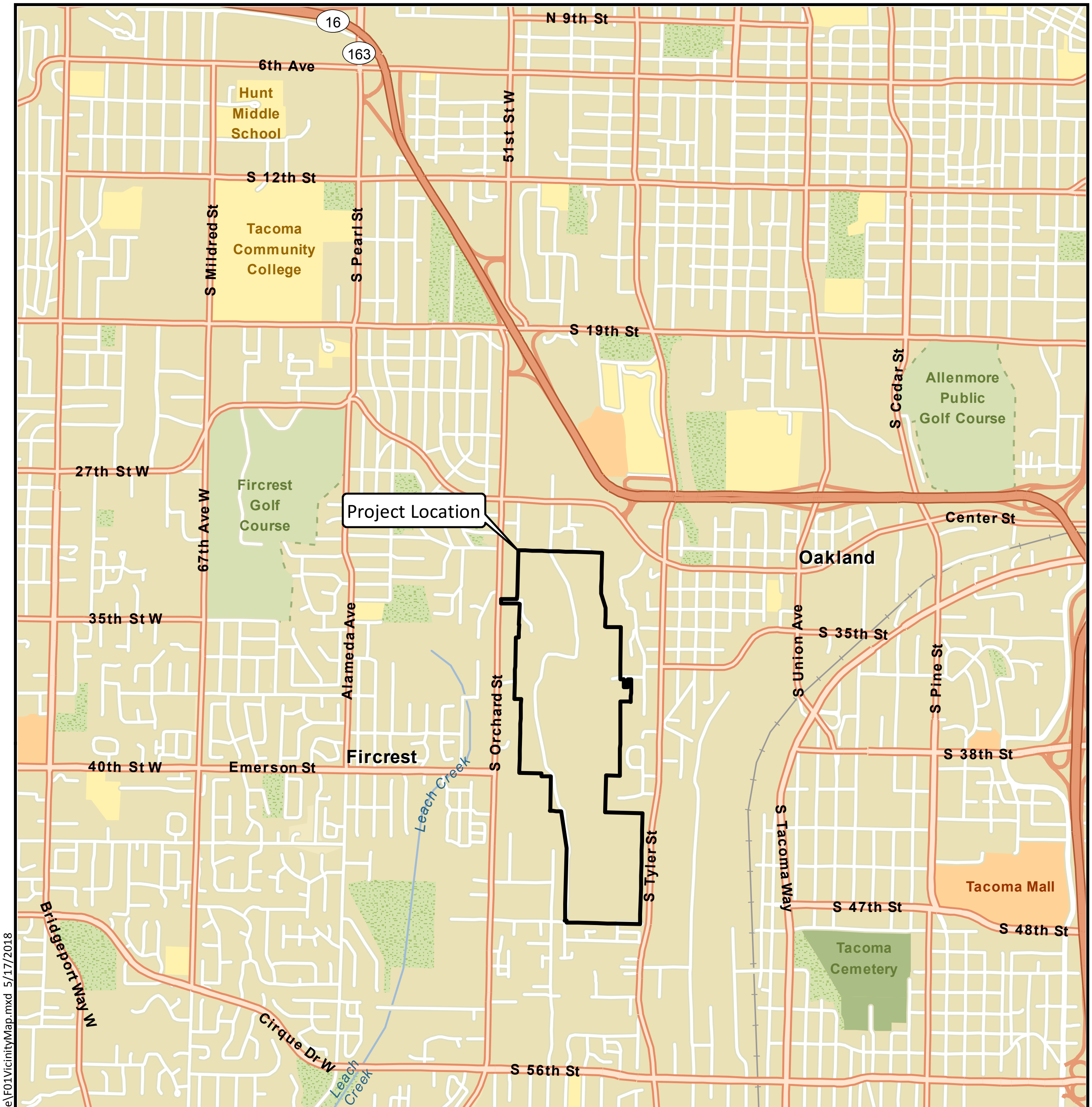

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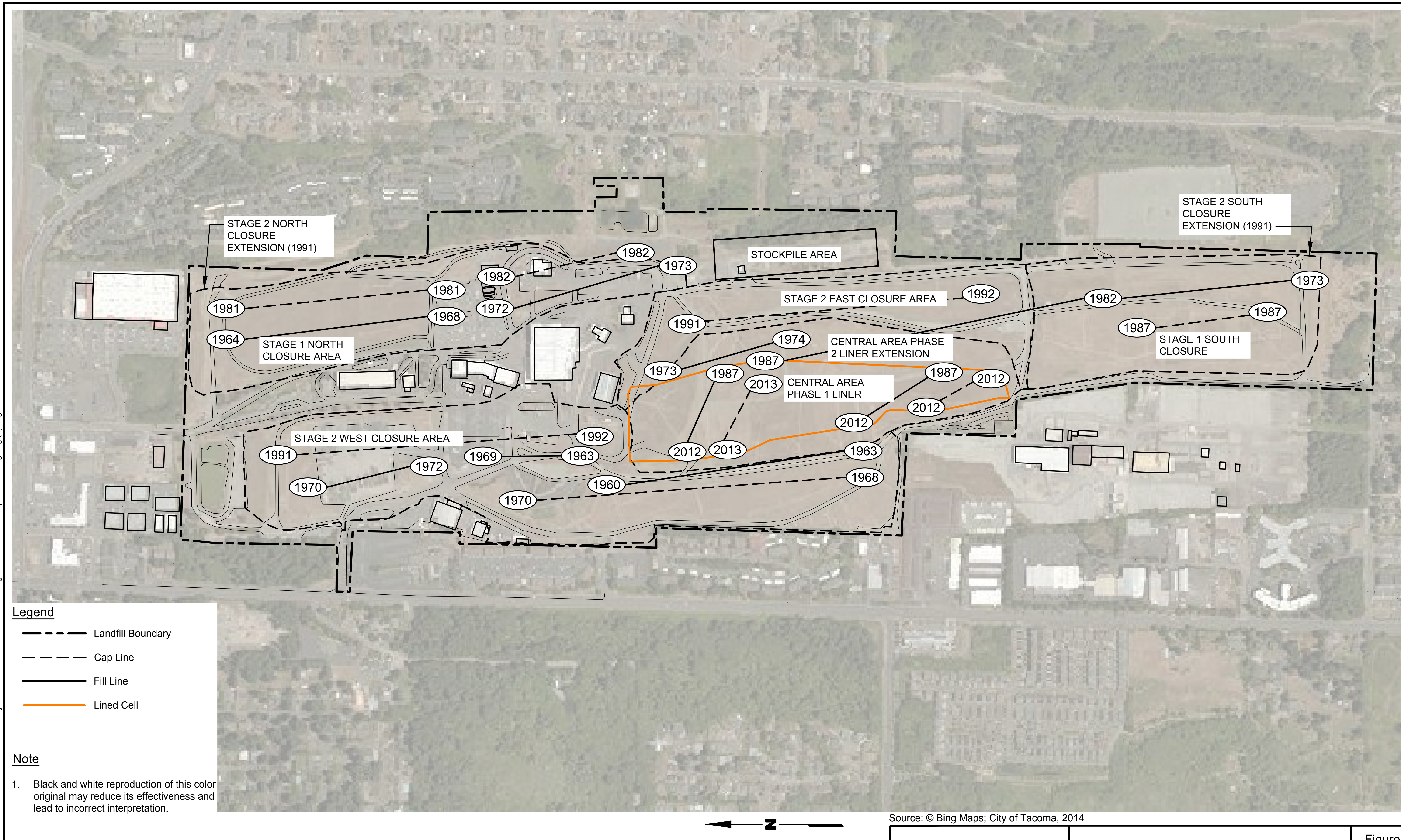
LANDAU ASSOCIATES

City of Tacoma Landfill Tacoma, Washington	**Vicinity Map**	Figure 1



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LANDAU ASSOCIATES

City of Tacoma Landfill
Tacoma, Washington

Sequence of Filling

Figure
2

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Note

1. Black and white reproduction of this color original may reduce its effectiveness and lead to incorrect interpretation.

Source: © Bing Maps; City of Tacoma, 2014

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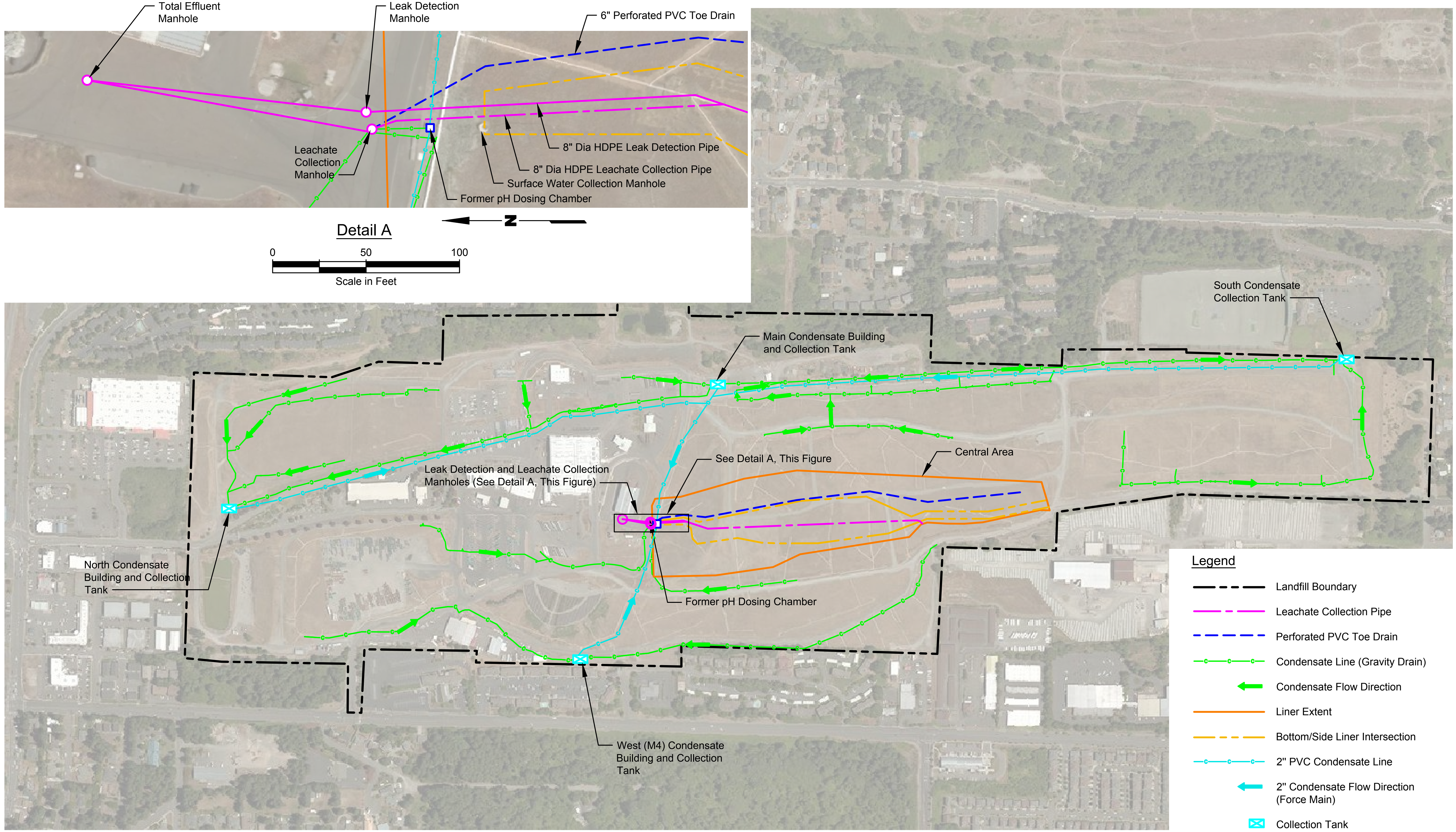
City of Tacoma Landfill
Tacoma, Washington

Landfill Areas

Figure
3



Source: © Bing 2015; City of Tacoma As-built Plans, 1988;

Notes
1. Black and white reproduction of this color original may reduce its effectiveness and lead to incorrect interpretation.
2. PVC = polyvinyl chloride, HDPE = high-density polyethylene
3. pH adjustment no longer required, therefore the former pH dosing chamber now serves as a condensate storage tank that gravity drains condensate to the sewer.

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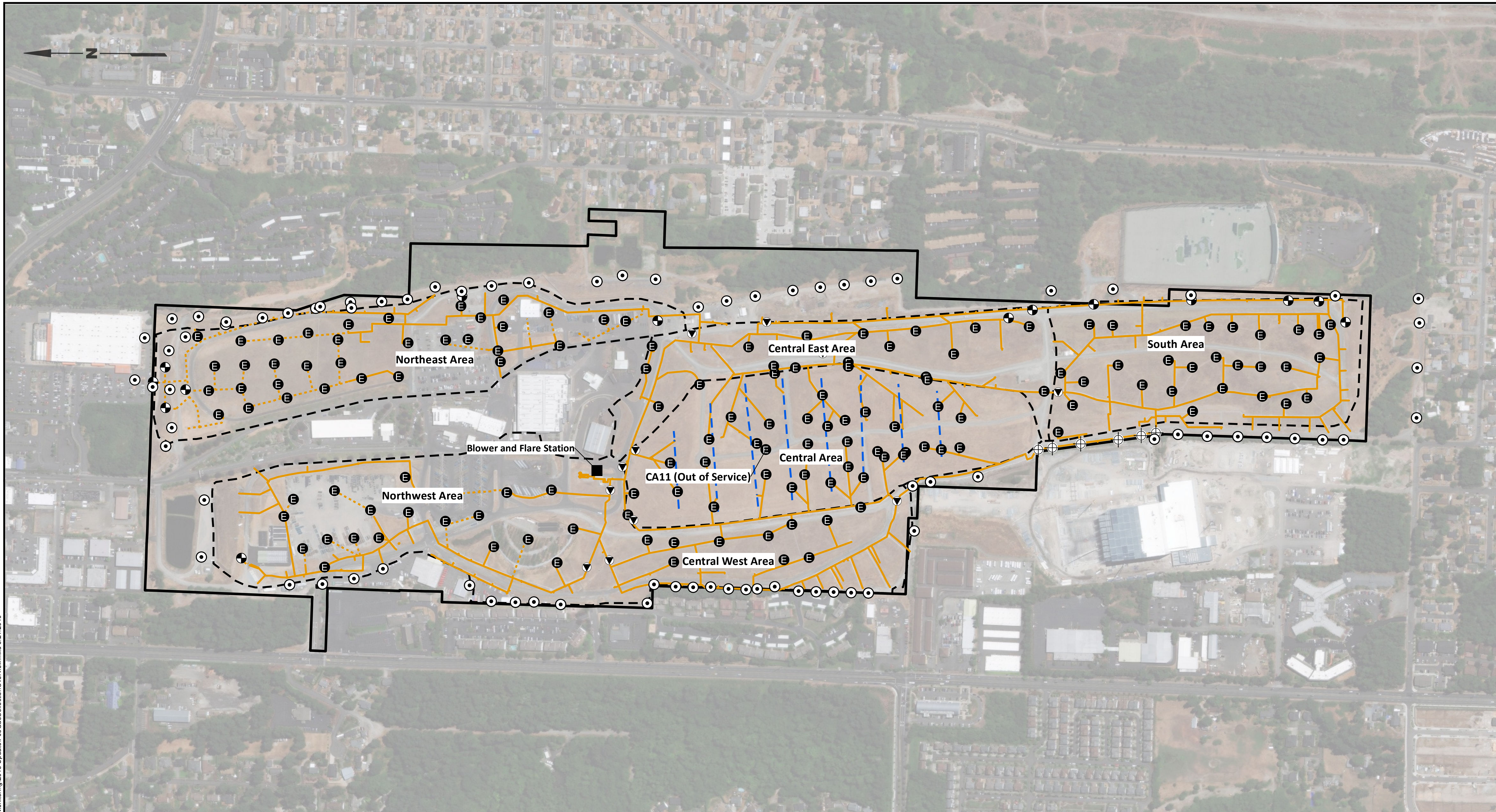
City of Tacoma Landfill
Tacoma, Washington

Leachate and Condensate Conveyance System

Figure 4



Legend

- Interior Extraction Well - Operating
- Perimeter Monitoring Probe
- Perimeter Extraction Well - Operating
- Monitoring Port
- Perimeter Extraction Well Converted to Monitoring Probe
- Landfill Boundary
- Cap Line
- Landfill Gas Collection Header (Exposed)
- Landfill Gas Collection Header (Buried)
- Horizontal Collector

Note

1. Black and white reproduction of this color original may reduce its effectiveness and lead to incorrect interpretation.

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Scale in Feet

Data Sources: Tacoma Landfill Stage 1-North Closure, Parametrix, May, 1990; Tacoma Landfill Stage 1-South Closure, Black & Veatch, June 1990; Tacoma Landfill Stage 2 Closure, Black & Veatch, June 1991; Esri World Imagery.

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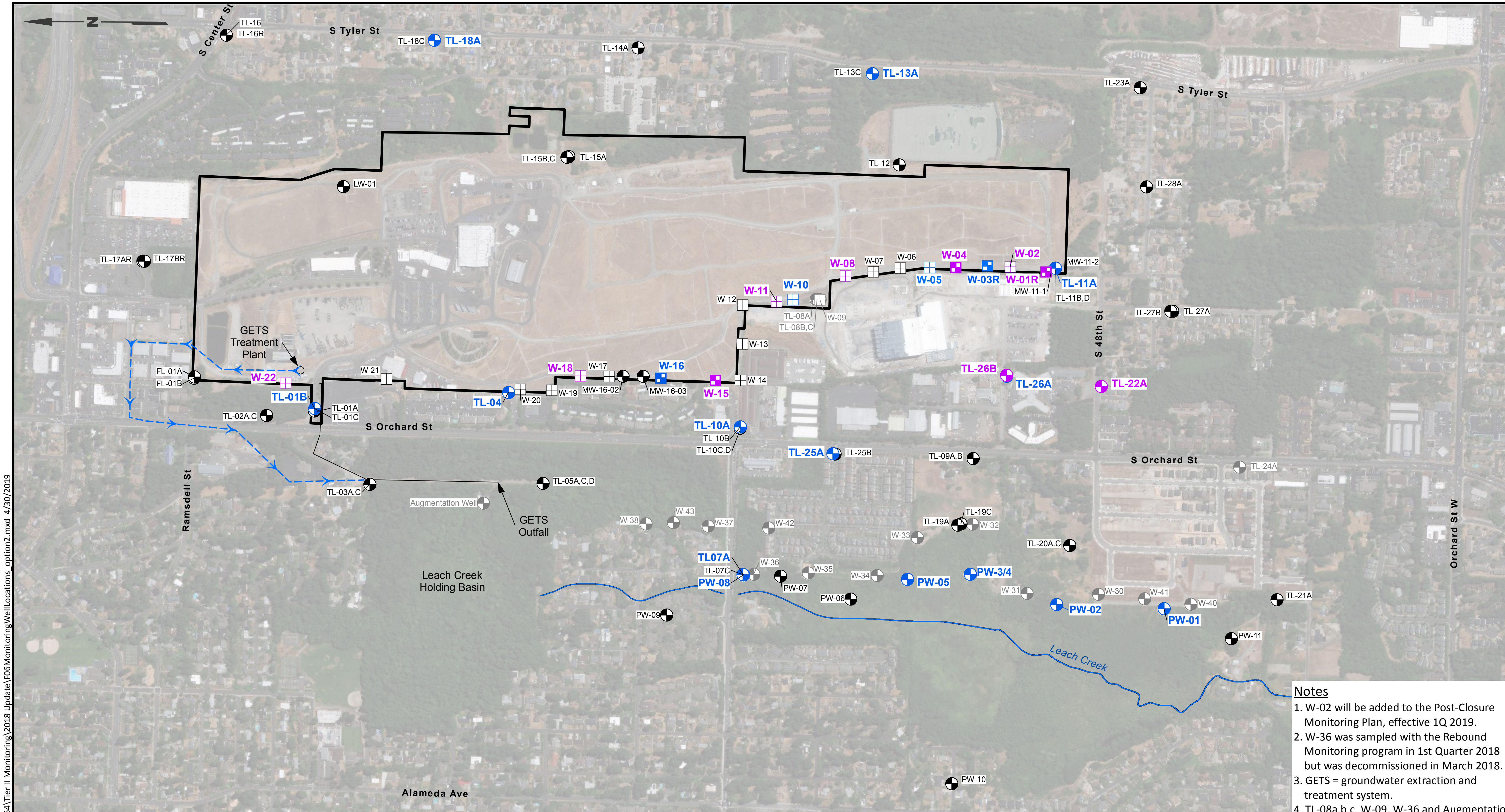
LANDAU ASSOCIATES

City of Tacoma Landfill Tacoma, Washington	**Gas Collection and Control System Overview**	Figure 5



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Notes

1. W-02 will be added to the Post-Closure Monitoring Plan, effective 1Q 2019.
2. W-36 was sampled with the Rebound Monitoring program in 1st Quarter 2018 but was decommissioned in March 2018.
3. GETS = groundwater extraction and treatment system.
4. TL-08a,b,c, W-09, W-36 and Augmentation Well were decommissioned in 2018.
5. Black and white reproduction of this color original may reduce its effectiveness and lead to incorrect interpretation.

Data Source: City of Tacoma; Esri World Imagery.

Legend

Well Type
- Monitoring Well
- GETS Extraction Well - Active
- GETS Extraction Well - Inactive

Well Status
- Post-Closure Monitoring Well
- Rebound Monitoring Well
- Not Currently Sampled
- Decommissioned

- Landfill Boundary
- Extracted Groundwater Flow Path

0 700 1,400

Scale in Feet

Landau Associates

City of Tacoma Landfill Tacoma, Washington	**Groundwater Well Network and GETS Features**	Figure 6

Legend

- Interior Extraction Well - Operating
- Perimeter Monitoring Probe
- Perimeter Extraction Well - Operating
- Monitoring Port
- Landfill Boundary
- Cap Line

Notes

1. Black and white reproduction of this color original may reduce its effectiveness and lead to incorrect interpretation.

Data Sources: Tacoma Landfill Stage 1-North Closure, Parametrix, May, 1990; Tacoma Landfill Stage 1-South Closure, Black & Veatch, June 1990; Tacoma Landfill Stage 2 Closure, Black & Veatch, June 1991; Esri World Imagery.

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LANDAU ASSOCIATES

City of Tacoma Landfill Tacoma, Washington	**Gas Collection and Control System** **Northeast Area**	Figure 7

Legend

- Interior Extraction Well - Operating; Extraction Well, Decommission
- Perimeter Monitoring Probe
- Perimeter Extraction Well - Operating
- Monitoring Port
- Landfill Boundary
- Cap Line

Notes

1. Black and white reproduction of this color original may reduce its effectiveness and lead to incorrect interpretation.

0 200 400

Scale in Feet

Data Sources: Tacoma Landfill Stage 1-North Closure, Parametrix, May, 1990; Tacoma Landfill Stage 1-South Closure, Black & Veatch, June 1990; Tacoma Landfill Stage 2 Closure, Black & Veatch, June 1991; Esri World Imagery.

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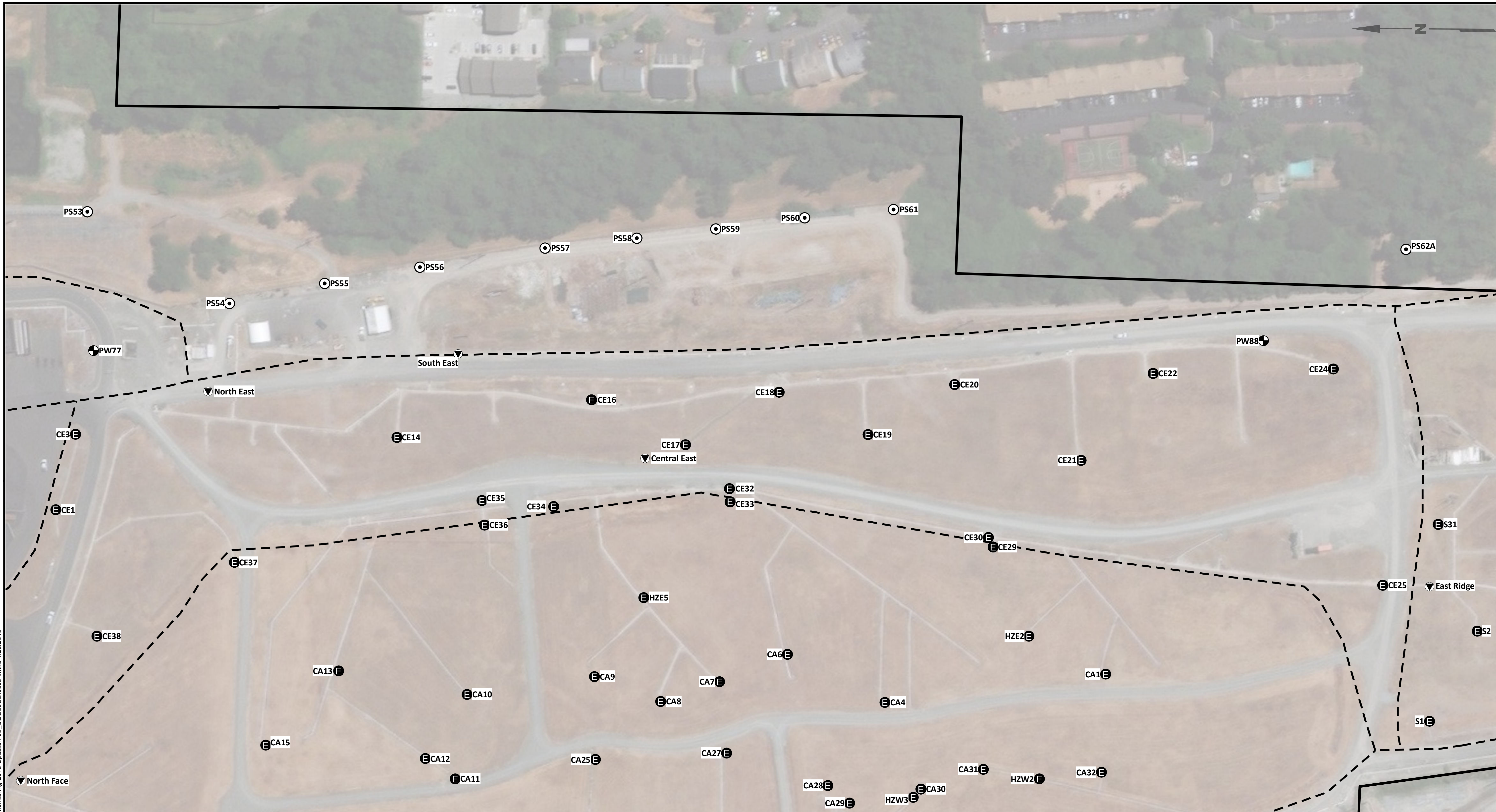
Landau Associates

City of Tacoma Landfill Tacoma, Washington	**Gas Collection and Control System Northwest Area**	Figure 8



Legend

- Interior Extraction Well - Operating
- Perimeter Monitoring Probe
- Perimeter Extraction Well - Operating
- Monitoring Port
- Landfill Boundary
- Cap Line

Notes

1. Black and white reproduction of this color original may reduce its effectiveness and lead to incorrect interpretation.

0 150 300

Scale in Feet

Data Sources: Tacoma Landfill Stage 1-North Closure, Parametrix, May, 1990; Tacoma Landfill Stage 1-South Closure, Black & Veatch, June 1990; Tacoma Landfill Stage 2 Closure, Black & Veatch, June 1991; Esri World Imagery.

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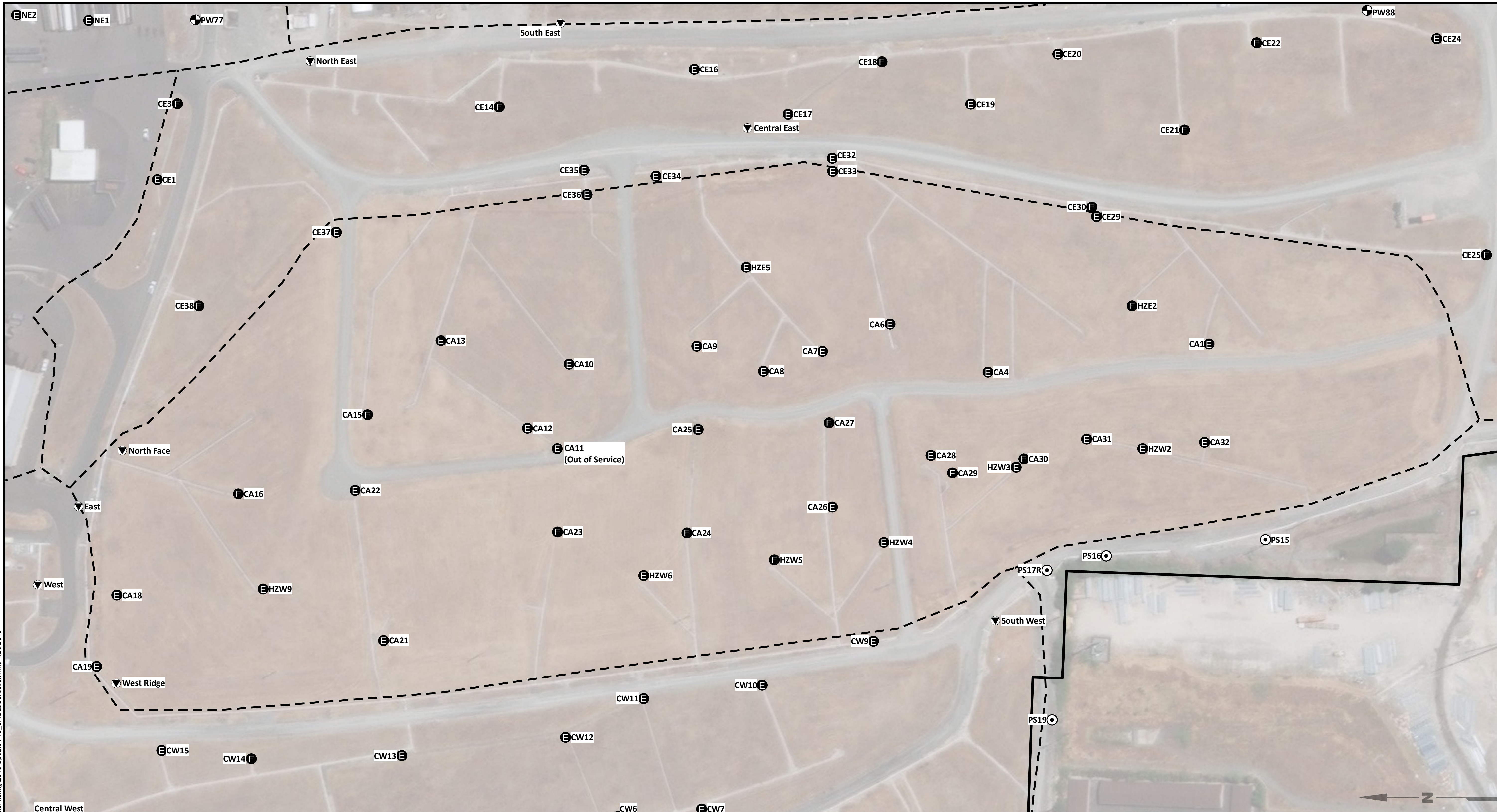
Landau Associates

City of Tacoma Landfill Tacoma, Washington	**Gas Collection and Control System Central East Area**	Figure 9



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Legend

- Interior Extraction Well - Operating
- Perimeter Monitoring Probe
- Perimeter Extraction Well - Operating
- Monitoring Port
- Landfill Boundary
- Cap Line

Notes

1. CA11 burned due to a subsurface fire in November 2018. From the surface location of the identifiable remains, borehole CA11 was decommissioned to the extent practicable in December 2018.
2. Black and white reproduction of this color original may reduce its effectiveness and lead to incorrect interpretation.

0 150 300

Scale in Feet

Data Sources: Tacoma Landfill Stage 1-North Closure, Parametrix, May, 1990; Tacoma Landfill Stage 1-South Closure, Black & Veatch, June 1990; Tacoma Landfill Stage 2 Closure, Black & Veatch, June 1991; Esri World Imagery.

Landau Associates

City of Tacoma Landfill Tacoma, Washington	**Gas Collection and Control System Central Area**	Figure 10

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Legend

- Interior Extraction Well - Operating
- Perimeter Monitoring Probe
- Perimeter Extraction Well - Operating
- Monitoring Port
- Landfill Boundary
- Cap Line

Note

1. Black and white reproduction of this color original may reduce its effectiveness and lead to incorrect interpretation.

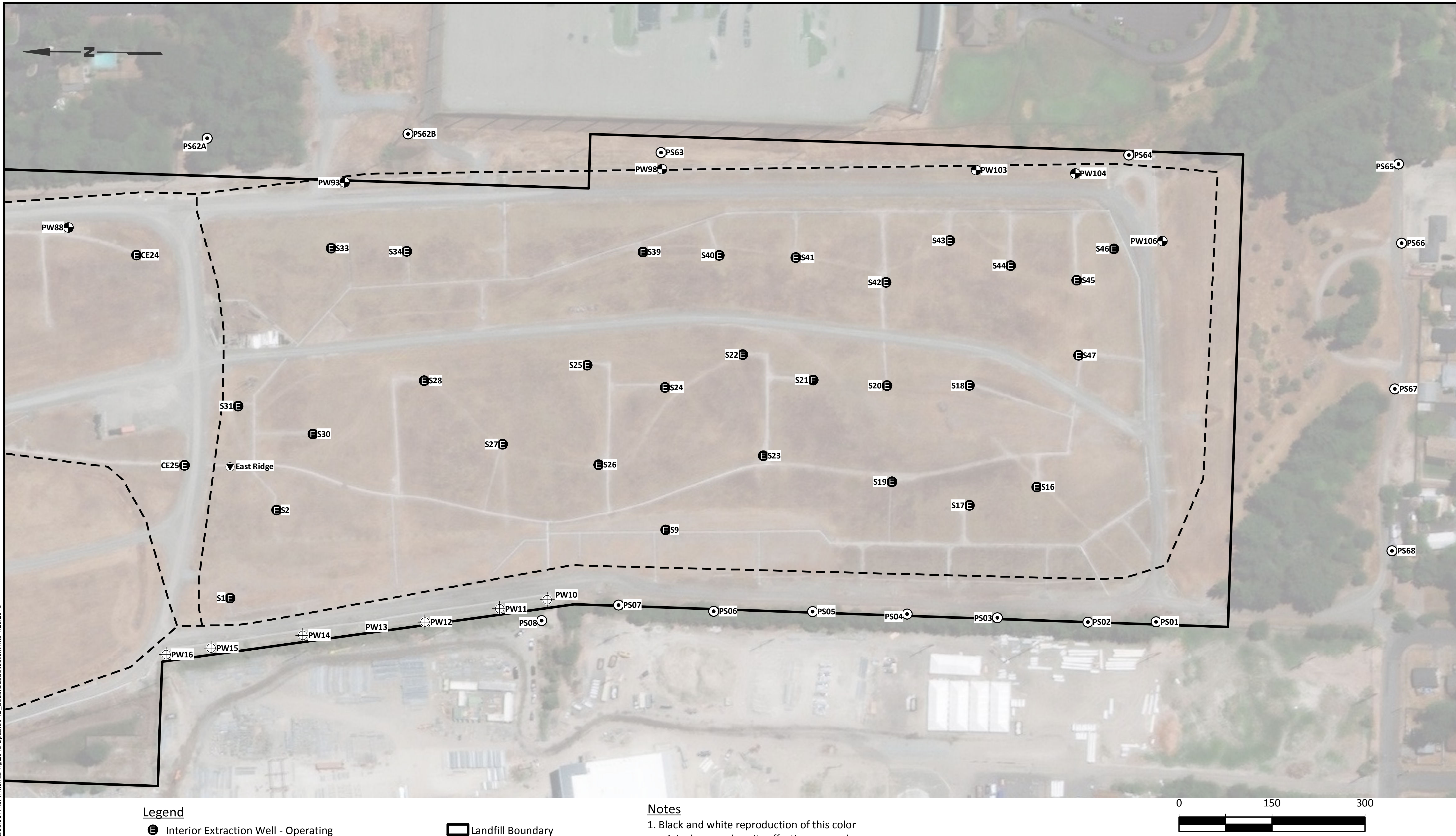
0 120 240

Scale in Feet

Data Sources: Tacoma Landfill Stage 1-North Closure, Parametrix, May, 1990; Tacoma Landfill Stage 1-South Closure, Black & Veatch, June 1990; Tacoma Landfill Stage 2 Closure, Black & Veatch, June 1991; Esri World Imagery.

LANDAU ASSOCIATES

City of Tacoma Landfill Tacoma, Washington	**Gas Collection and Control System** **Central West Area**	Figure 11



Legend

- Interior Extraction Well - Operating
- Perimeter Monitoring Probe
- Perimeter Extraction Well - Operating
- Perimeter Extraction Well Converted to Monitoring Probe
- Monitoring Port
- Landfill Boundary
- Cap Line

Notes

1. Black and white reproduction of this color original may reduce its effectiveness and lead to incorrect interpretation.

Data Sources: Tacoma Landfill Stage 1-North Closure, Parametrix, May, 1990; Tacoma Landfill Stage 1-South Closure, Black & Veatch, June 1990; Tacoma Landfill Stage 2 Closure, Black & Veatch, June 1991; Esri World Imagery.

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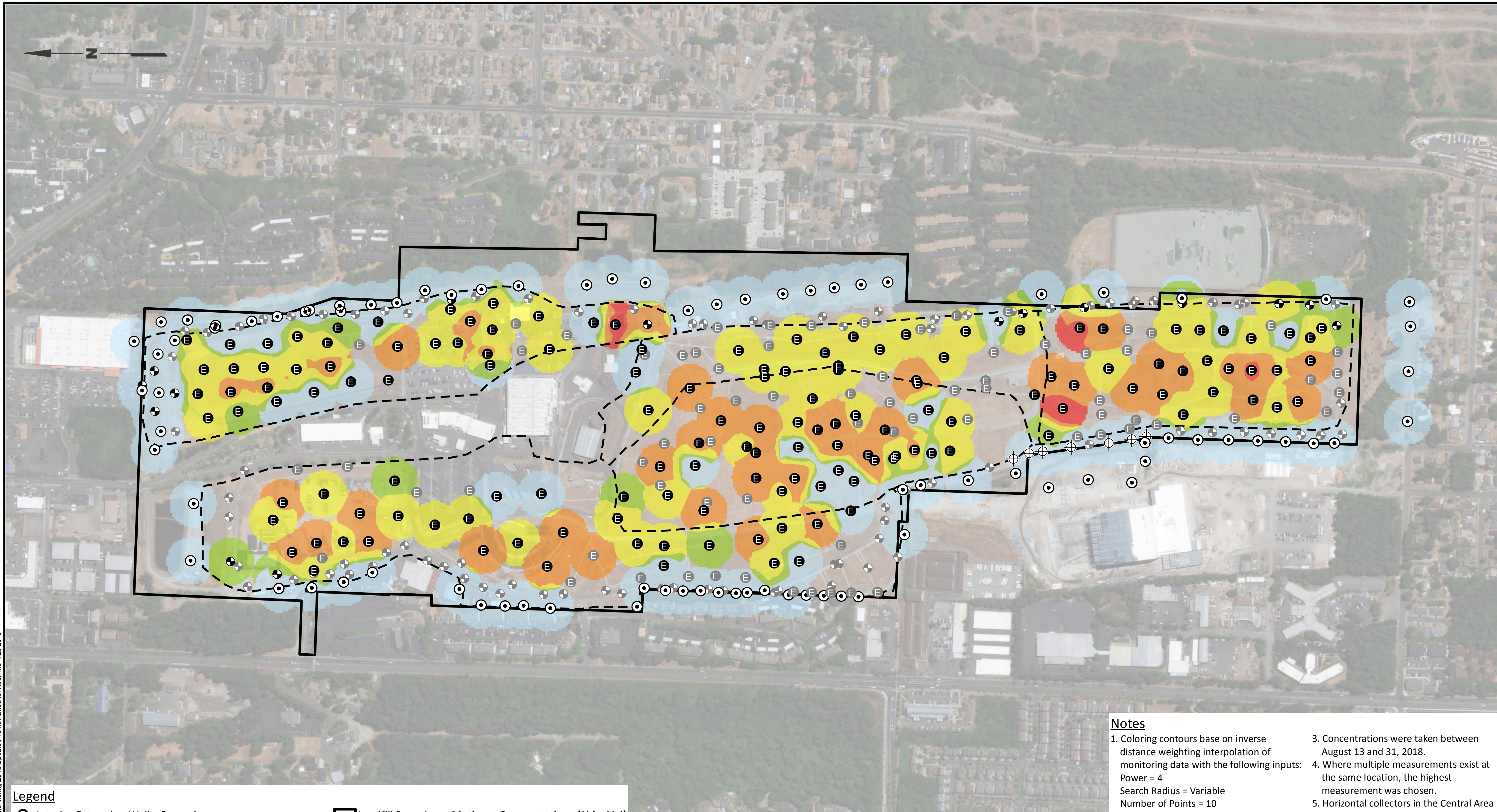
LANDAU ASSOCIATES

City of Tacoma Landfill Tacoma, Washington	**Gas Collection and Control System South Area**	Figure 12



Legend

- Interior Extraction Well - Operating
- Interior Extraction Well - Not Operating
- Monitoring Probe
- Perimeter Extraction Well - Operating
- Perimeter Extraction Well - Not Operating
- Perimeter Extraction Well - Converted to Monitoring Probe
- Landfill Boundary
- Cap Line

Methane Concentrations (% by Vol)

- 0 - 5
- 5 - 15
- 15 - 35
- 35 - 55
- 55+

0 500 1,000

Scale in Feet

Notes

1. Coloring contours base on inverse distance weighting interpolation of monitoring data with the following inputs:
   Power = 4
   Search Radius = Variable
   Number of Points = 10
   Maximum Distance = 125 ft
2. Section boundaries are not included in the interpolation.
3. Concentrations were taken between August 13 and 31, 2018.
4. Where multiple measurements exist at the same location, the highest measurement was chosen.
5. Horizontal collectors in the Central Area are not included in this analysis.
6. Black and white reproduction of this color original may reduce its effectiveness and lead to incorrect interpretation.

Data Sources: Tacoma Landfill Stage 1-North Closure, Parametrix, May, 1990; Tacoma Landfill Stage 1-South Closure, Black & Veatch, June 1990; Tacoma Landfill Stage 2 Closure, Black & Veatch, June 1991; Esri World Imagery.

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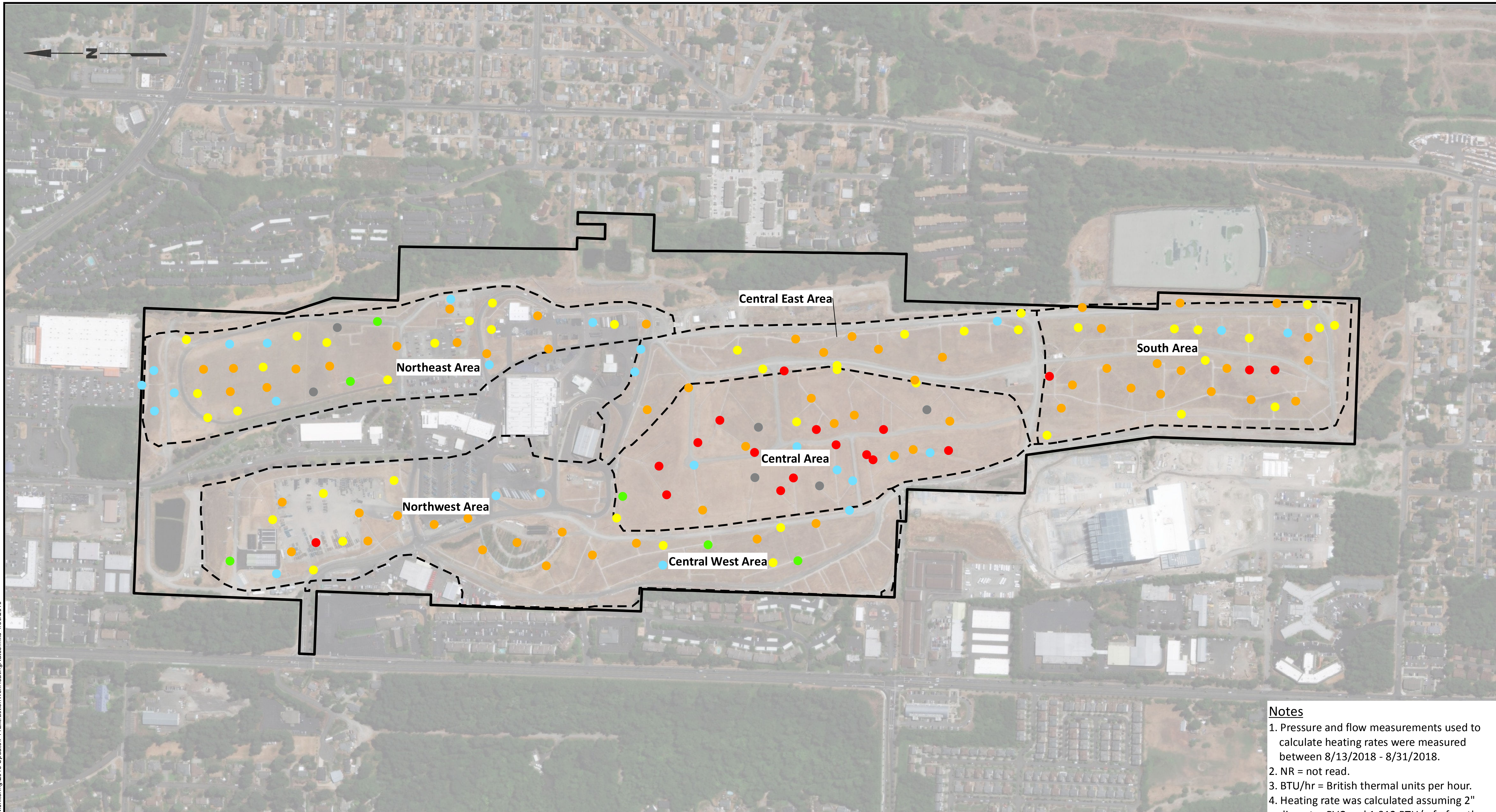
LANDAU ASSOCIATES

City of Tacoma Landfill Tacoma, Washington	**Methane Concentrations: 3rd Quarter 2018 Site-Wide**	Figure 13



Notes
1. Pressure and flow measurements used to calculate heating rates were measured between 8/13/2018 - 8/31/2018.
2. NR = not read.
3. BTU/hr = British thermal units per hour.
4. Heating rate was calculated assuming 2" diameter PVC and 1,012 BTU/scf of methane.
5. Black and white reproduction of this color original may reduce its effectiveness and lead to incorrect interpretation.

Legend
- Extraction Well
- Landfill Boundary
- Cap Line

Heating Rate (BTU/hr)
- NR
- 0
- 0 - 10,000
- 10,000 - 100,000
- 100,000 - 1,000,000
- >1,000,000

0 500 1,000
Scale in Feet

Data Sources: Tacoma Landfill Stage 1-North Closure, Parametrix, May, 1990; Tacoma Landfill Stage 1-South Closure, Black & Veatch, June 1990; Tacoma Landfill Stage 2 Closure, Black & Veatch, June 1991; Esri World Imagery.

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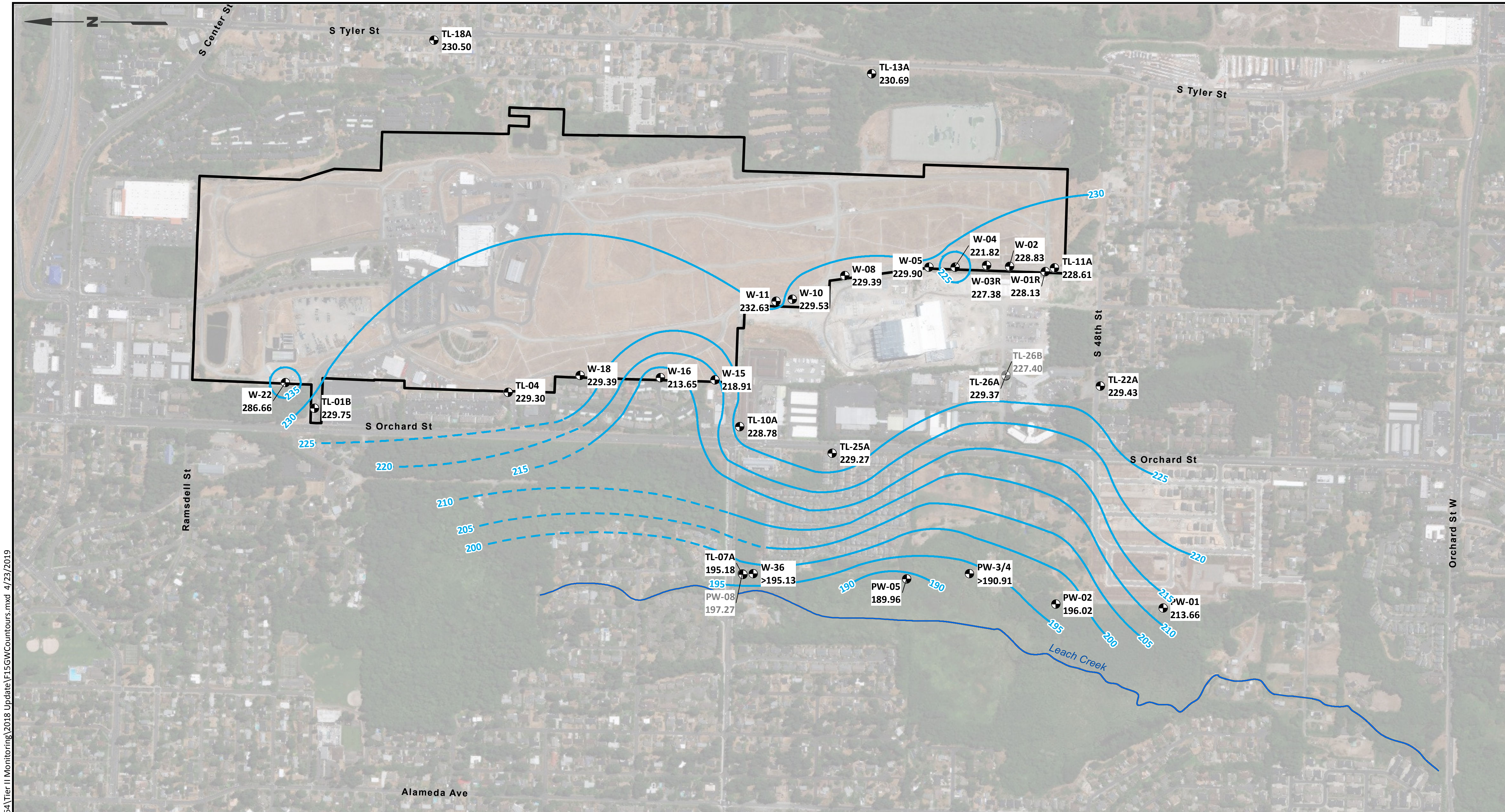
Landau Associates

City of Tacoma Landfill
Tacoma, Washington

Extraction Well Heating Rates
3rd Quarter 2018
Site-Wide

Figure
14



Legend

- Monitoring Well
- Monitoring Well (measurement not used for contour generation)
- Landfill Boundary
- Groundwater Elevation Contour

Notes

1. Active extraction wells include W-01R, W-04, W-15, and W-16.
2. PW-01, PW-05, PW-3/4 and W-36 are under artesian conditions. Measurements for these wells are approximate.
3. Water level measurements were taken on July 26th, 2018.
4. Black and white reproduction of this color original may reduce its effectiveness and lead to incorrect interpretation.

0 700 1,400
Scale in Feet

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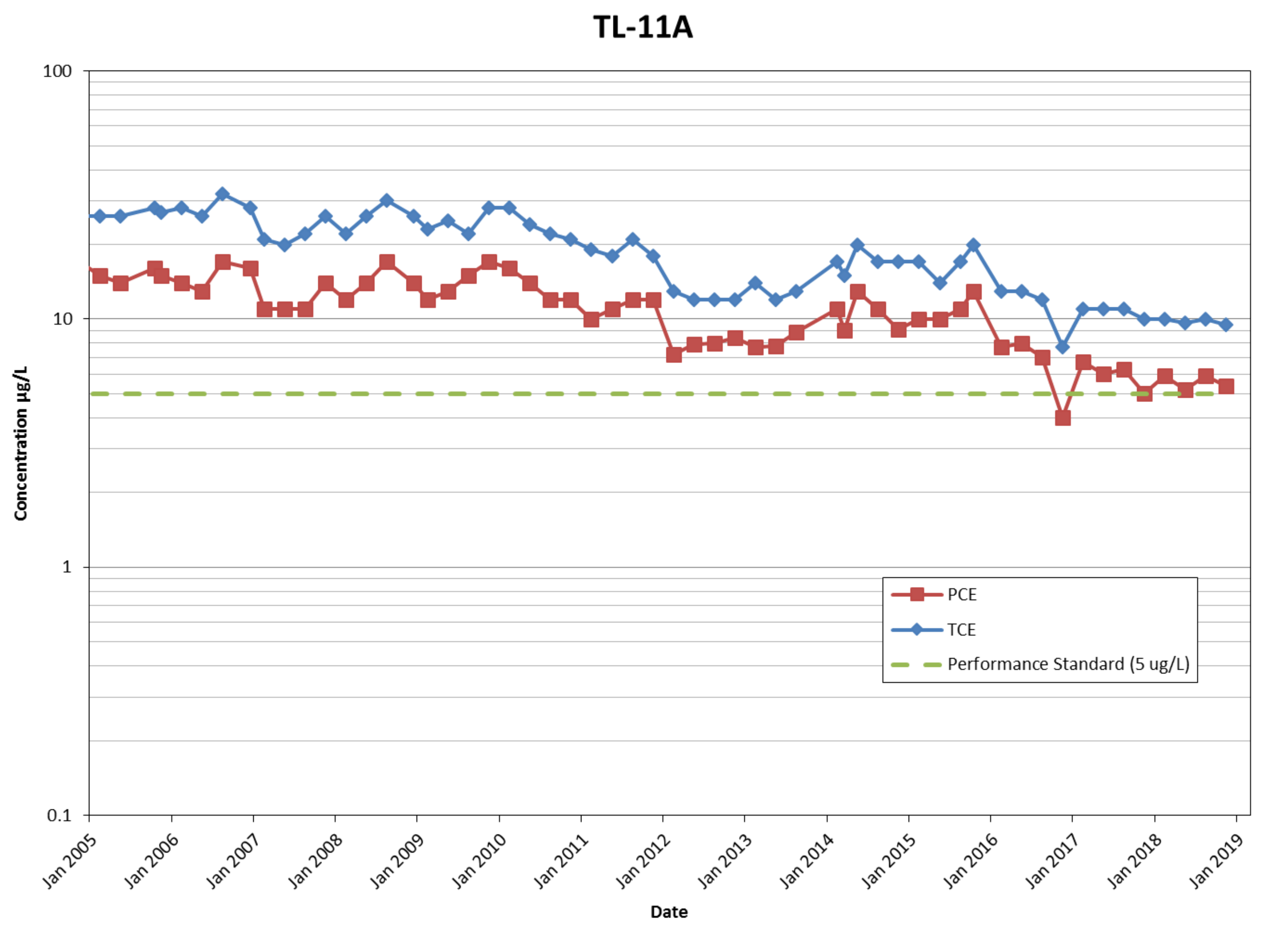
LANDAU ASSOCIATES

Data Source: City of Tacoma; Esri World Imagery.

City of Tacoma Landfill
Tacoma, Washington

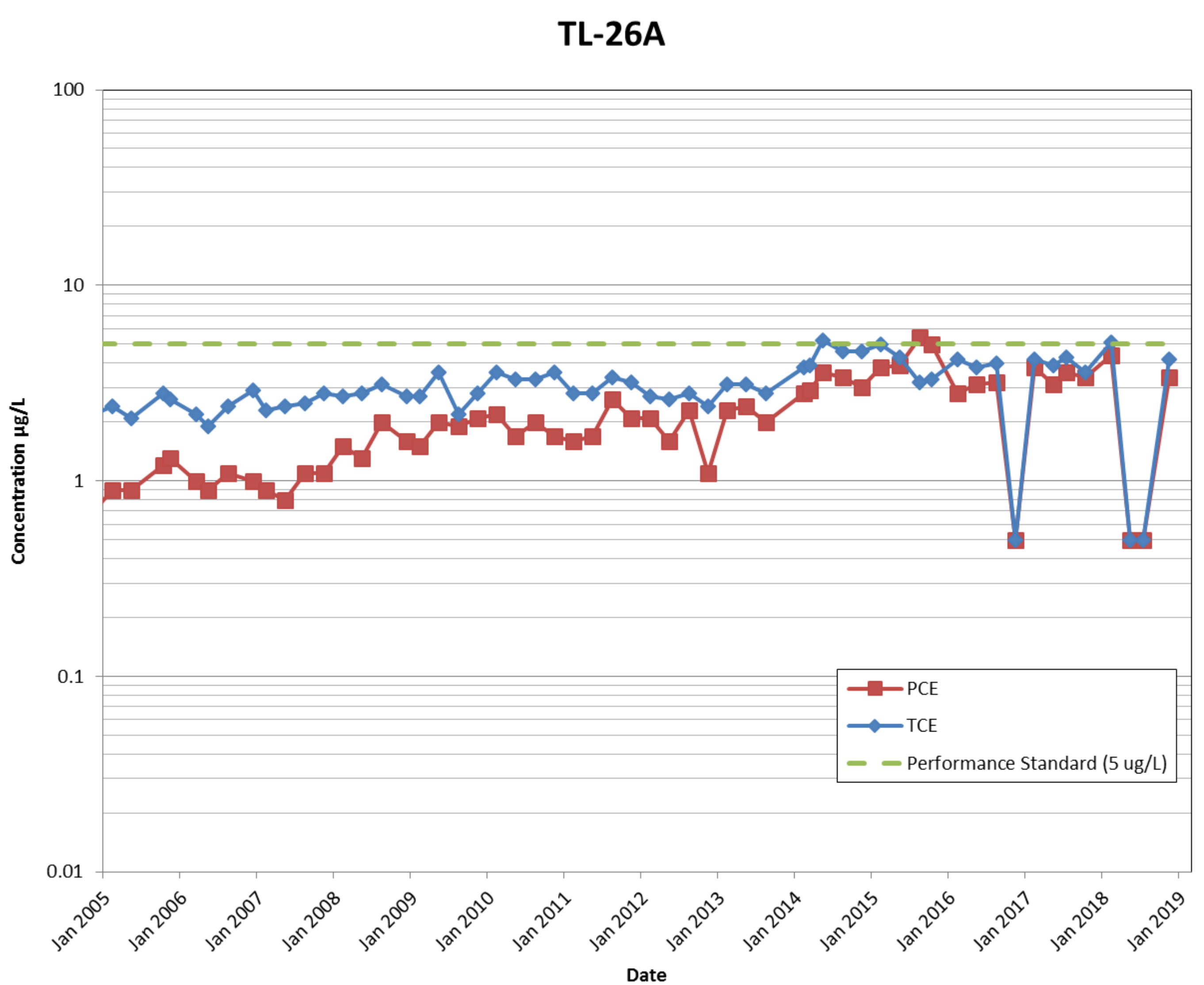
Groundwater Elevation Contours - 3rd Quarter 2018

Figure
15



LANDAU ASSOCIATES

City of Tacoma Landfill Tacoma, Washington	**Time Series Plot** **TL-11A VOCs**	Figure 16

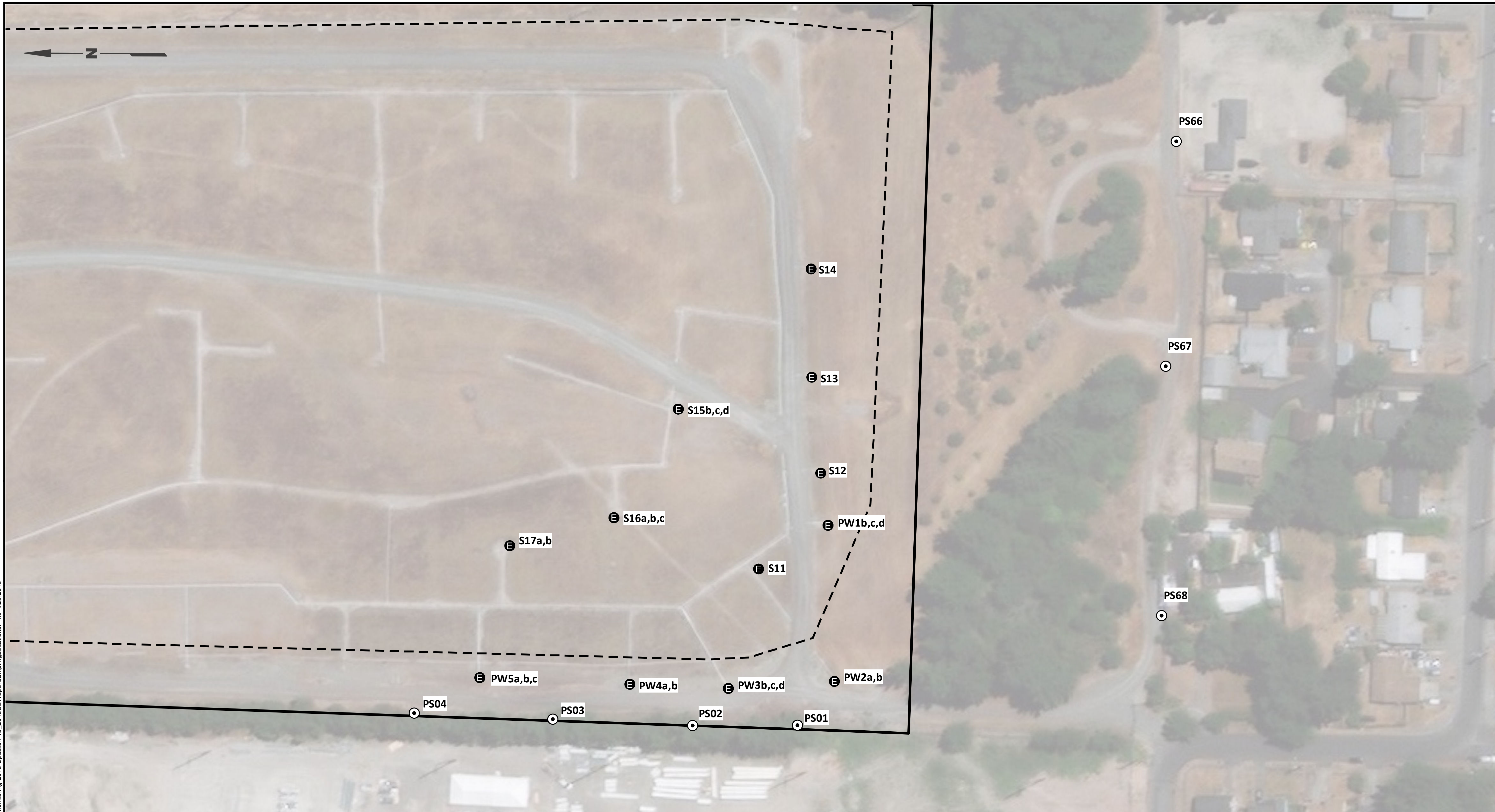


LANDAU ASSOCIATES

City of Tacoma Landfill
Tacoma, Washington

Time Series Plot
TL-26A VOCs

Figure
17



Legend
- Extraction Well
- Monitoring Probe
- Landfill Boundary
- Cap Line

Notes
1. Black and white reproduction of this color original may reduce its effectiveness and lead to incorrect interpretation.

0 100 200
Scale in Feet

Landau Associates

Data Sources: Esri World Imagery.

City of Tacoma Landfill
Tacoma, Washington

2018 Soil Vapor Sampling Locations

Figure 18

Table 1
Landfill Areas Gas Monitoring Frequency
City of Tacoma Landfill
Tacoma, Washington

Location or Area Description	Elkins / Juniper Abbreviation	2018 Monitoring Frequency
Central Area	CA	Quarterly
Central East	CE	Quarterly
Central West	CW	Quarterly
Northeast	NE	Quarterly
Northwest	NW	Quarterly
South	S	Quarterly
Northeast PS	NEPS	Biweekly (twice per month)
Northwest PS	NWPS	Biweekly (twice per month)
Southeast PS	SEPS	Biweekly (twice per month)
Southwest PS	SWPS	Biweekly (twice per month)
Offsite HD Probes	DAILY HD	Biweekly (twice per month)
Onsite HD Probes	WEEKLY HD	Biweekly (twice per month)
Monthly HD Extraction Network	MONTHLY HD	Monthly
Blower/Flare Station	COT	Daily
Monitoring Points	MONITORING POINTS	Weekly

Abbreviations/Acronyms:
COT = City of Tacoma
HD = Home Depot Area
PS = probe station

Table 2
2018 Groundwater and Surface Water Monitoring Locations
City of Tacoma Landfill
Tacoma, Washington

Program	Monitoring Purpose	Sample ID	Well/Sample Structure Type	Designated Sampling Equipment	On-Site or Off-Site	Sampling Frequency	Laboratory Analyses
Post-Closure Monitoring	Background	TL-13A	Monitoring Well	Portable Grundfos	Off-Site	Q	Volatiles, Metals, Conventionals, and Field Parameters[b]
	Background	TL-18A	Monitoring Well	Portable Grundfos	Off-Site	Q	
	POC	TL-01B	Monitoring Well	Dedicated Grundfos	On-Site	Q	
	POC	TL-04	Monitoring Well	Dedicated Grundfos	Off-Site	Q	
	POC	TL-11A	Monitoring Well	Extraction Pump	On-Site	Q	
	POC	W-03R	Extraction Well	Portable Grundfos	On-Site	Q	
	POC	W-05	Extraction Well	Extraction Pump	On-Site	Q	
	POC	W-10	Extraction Well	Extraction Pump	On-Site	Q	
	POC	W-16	Extraction Well	Extraction Pump	On-Site	Q	
	Downgradient	PW-01	Perfomance Well	Dedicated Grundfos	Off-Site	Q	
	Downgradient	PW-02	Perfomance Well	Dedicated Grundfos	Off-Site	Q	
	Downgradient	PW-3/4	Perfomance Well	Artesian	Off-Site	Q	
	Downgradient	PW-05	Perfomance Well	Dedicated Grundfos	Off-Site	Q	
	Downgradient	PW-08	Perfomance Well	Dedicated Grundfos	Off-Site	Q	
	Downgradient	TL-07A	Monitoring Well	Dedicated Grundfos	Off-Site	Q	
	Downgradient	TL-10A	Monitoring Well	Dedicated Grundfos	Off-Site	Q	
	Downgradient	TL-25A	Monitoring Well	Dedicated Grundfos	Off-Site	Q	
	Downgradient	TL-26A	Monitoring Well	Dedicated Grundfos	Off-Site	Q	
	Surface Water Monitoring	GETS Outfall	Outfall	Grab Sample	Off-Site	Q	
Rebound Monitoring	Rebound Monitoring	TL-22A	Monitoring Well	Dedicated Grundfos	Off-Site	Q	Volatiles[b]
	Rebound Monitoring	TL-26B	Monitoring Well	Dedicated Grundfos	Off-Site	Q	
	Rebound Monitoring	W-01R	Extraction Well	Extraction Pump	On-Site	Q	
	Rebound Monitoring	W-02	Extraction Well	Portable Grundfos	On-Site	Q	
	Rebound Monitoring	W-04	Extraction Well	Extraction Pump	On-Site	Q	
	Rebound Monitoring	W-08	Extraction Well	Extraction Pump	On-Site	Q	
	Rebound Monitoring	W-11	Extraction Well	Extraction Pump	On-Site	Q	
	Rebound Monitoring	W-15	Extraction Well	Extraction Pump	On-Site	Q	
	Rebound Monitoring	W-18	Extraction Well	Extraction Pump	On-Site	Q	
	Rebound Monitoring	W-22	Extraction Well	Extraction Pump	On-Site	Q	
	Rebound Monitoring	W-36[a]	Extraction Well	Extraction Pump	Off-Site	1st Q Only	

Notes:

1. Quarterly samples were collected in February, May, July, and November.
2. Water elevation monitoring was completed at all listed groundwater monitoring locations quarterly.

[a] Well W-36 was decommissioned in March 2018.

[b] Samples were collected and analyzed in accordance with Post-Closure Water Quality Monitoring Sampling and Analysis Plan (LAI 2017b).

Abbreviations and Acronyms:

POC = point of compliance
GETS = groundwater extraction and treatment system
Q = quarterly

Table 3
Groundwater Performance Standards
City of Tacoma Landfill
Tacoma, Washington

Parameter	Units	MCL[a]	HBC[b]	Method 624 MDL	Groundwater Performance Standard Criterion	Groundwater Performance Standard[c]	Early Warning Value Criterion	Early Warning Value
1,1,1-TCE	µg/L	200	--	0.5	MCL	200	20% of MCL	40
1,1-DCA	µg/L	--	20	0.5	HBC	20	20% of HBC	4
1,2-DCA	µg/L	5	--	0.5	MCL	5	20% of MCL	1
1,2-DCE	µg/L	--	--	0.5	Lowest MCL	70	Lowest EWV	14
1,2-cDCE	µg/L	70	--	--	MCL	70	20% of MCL	14
trans-1,2-DCE	µg/L	100	--	--	MCL	100	20% of MCL	20
Benzene	µg/L	5	--	0.5	MCL	5	20% of MCL	1
Chloroethane	µg/L	--	20	0.5	HBC	20	20% of HBC	4
PCE	µg/L	5	--	0.5	MCL	5	20% of MCL	1
TCE	µg/L	5	--	0.5	MCL	5	20% of MCL	1
VC	µg/L	2	--	0.5	MCL	2	20% of MCL	0.5[d]

Notes:

-- = not applicable

[a] Code of Federal Regulations: 40 CFR 141 (7-1-95 ed.) Safe Drinking Water Act MCL.

[b] Tacoma Landfill Consent Decree (5/17/91) HBC.

[c] Surface water performance standards are not specified in the Consent Decree. Surface water results will be compared to the applicable groundwater performance standards.

[d] EWV established at the MDL of 0.5 µg/L.

Abbreviations / Acronyms:

cDCE = cis-dichloroethene
DCA = dichloroethane
DCE = dichloroethene
EWV = early warning value
HBC = health-based criteria
MCL = maximum contaminant level
MDL = method detection limit
PCE = tetrachloroethene
TCE = trichloroethene
µg/L = micrograms per liter
VC = vinyl chloride
% = percent

Table 4
2018 Groundwater Volatile Organic Compounds Results
City of Tacoma Landfill
Tacoma, Washington

Program	Location	Analyte	Performance Standard (µg/L)	Maximum Detection (µg/L)	No. of Detections	No. of Samples
Post-Closure Monitoring	PW-01	1,1,1-Trichloroethane	200	ND	0	4
		1,1-Dichloroethane	20	**1.0**	4	4
		1,2-Dichloroethane	5	ND	0	4
		Benzene	5	ND	0	4
		Chloroethane	20	ND	0	4
		cis-1,2-Dichloroethene	70	ND	0	1
		Tetrachloroethene	5	ND	0	4
		Total 1,2-Dichloroethene	70	ND	0	4
		trans-1,2-Dichloroethene	100	ND	0	1
		Trichloroethene	5	ND	0	4
		Vinyl Chloride	2	ND	0	4
	PW-02	1,1,1-Trichloroethane	200	ND	0	4
		1,1-Dichloroethane	20	**1.5**	4	4
		1,2-Dichloroethane	5	ND	0	4
		Benzene	5	ND	0	4
		Chloroethane	20	ND	0	4
		cis-1,2-Dichloroethene	70	**0.7**	1	1
		Tetrachloroethene	5	ND	0	4
		Total 1,2-Dichloroethene	70	**0.7**	4	4
		trans-1,2-Dichloroethene	100	ND	0	1
		Trichloroethene	5	ND	0	4
		Vinyl Chloride	2	ND	0	4
	PW-05	1,1,1-Trichloroethane	200	ND	0	4
		1,1-Dichloroethane	20	ND	0	4
		1,2-Dichloroethane	5	ND	0	4
		Benzene	5	ND	0	4
		Chloroethane	20	ND	0	4
		cis-1,2-Dichloroethene	70	ND	0	1
		Tetrachloroethene	5	ND	0	4
		Total 1,2-Dichloroethene	70	ND	0	4
		trans-1,2-Dichloroethene	100	ND	0	1
		Trichloroethene	5	ND	0	4
		Vinyl Chloride	2	ND	0	4
	PW-08	1,1,1-Trichloroethane	200	ND	0	4
		1,1-Dichloroethane	20	ND	0	4
		1,2-Dichloroethane	5	ND	0	4
		Benzene	5	ND	0	4
		Chloroethane	20	ND	0	4
		cis-1,2-Dichloroethene	70	ND	0	1
		Tetrachloroethene	5	ND	0	4
		Total 1,2-Dichloroethene	70	ND	0	4
		trans-1,2-Dichloroethene	100	ND	0	1
		Trichloroethene	5	ND	0	4
		Vinyl Chloride	2	**0.7**	4	4
	PW-3/4	1,1,1-Trichloroethane	200	ND	0	4
		1,1-Dichloroethane	20	**2**	4	4
		1,2-Dichloroethane	5	**0.6**	4	4
		Benzene	5	ND	0	4
		Chloroethane	20	ND	0	4
		cis-1,2-Dichloroethene	70	**0.7**	1	1

Table 4
2018 Groundwater Volatile Organic Compounds Results
City of Tacoma Landfill
Tacoma, Washington

Program	Location	Analyte	Performance Standard (µg/L)	Maximum Detection (µg/L)	No. of Detections	No. of Samples
Post-Closure Monitoring	PW-3/4	Tetrachloroethene	5	ND	0	4
		Total 1,2-Dichloroethene	70	**0.8**	4	4
		trans-1,2-Dichloroethene	100	ND	0	1
		Trichloroethene	5	ND	0	4
		Vinyl Chloride	2	ND	0	4
	TL-01B	1,1,1-Trichloroethane	200	ND	0	4
		1,1-Dichloroethane	20	ND	0	4
		1,2-Dichloroethane	5	ND	0	4
		Benzene	5	ND	0	4
		Chloroethane	20	ND	0	4
		cis-1,2-Dichloroethene	70	**5.1**	1	1
		Tetrachloroethene	5	ND	0	4
		Total 1,2-Dichloroethene	70	**5.3**	4	4
		trans-1,2-Dichloroethene	100	ND	0	1
		Trichloroethene	5	ND	0	4
		Vinyl Chloride	2	**0.2**	2	4
	TL-04	1,1,1-Trichloroethane	200	ND	0	4
		1,1-Dichloroethane	20	ND	0	4
		1,2-Dichloroethane	5	**2.0**	4	4
		Benzene	5	ND	0	4
		Chloroethane	20	ND	0	4
		cis-1,2-Dichloroethene	70	**2.6**	1	1
		Tetrachloroethene	5	ND	0	4
		Total 1,2-Dichloroethene	70	**2.8**	4	4
		trans-1,2-Dichloroethene	100	ND	0	1
		Trichloroethene	5	ND	0	4
		Vinyl Chloride	2	**0.2**	2	4
	TL-07A	1,1,1-Trichloroethane	200	ND	0	4
		1,1-Dichloroethane	20	ND	0	4
		1,2-Dichloroethane	5	ND	0	4
		Benzene	5	ND	0	4
		Chloroethane	20	ND	0	4
		cis-1,2-Dichloroethene	70	ND	0	1
		Tetrachloroethene	5	ND	0	4
		Total 1,2-Dichloroethene	70	ND	0	4
		trans-1,2-Dichloroethene	100	ND	0	1
		Trichloroethene	5	ND	0	4
		Vinyl Chloride	2	**1.7**	4	4
	TL-10A	1,1,1-Trichloroethane	200	ND	0	4
		1,1-Dichloroethane	20	ND	0	4
		1,2-Dichloroethane	5	ND	0	4
		Benzene	5	ND	0	4
		Chloroethane	20	ND	0	4
		cis-1,2-Dichloroethene	70	ND	0	1
		Tetrachloroethene	5	ND	0	4
		Total 1,2-Dichloroethene	70	ND	0	4
		trans-1,2-Dichloroethene	100	ND	0	1
		Trichloroethene	5	ND	0	4
		Vinyl Chloride	2	ND	0	4

Table 4
2018 Groundwater Volatile Organic Compounds Results
City of Tacoma Landfill
Tacoma, Washington

Program	Location	Analyte	Performance Standard (µg/L)	Maximum Detection (µg/L)	No. of Detections	No. of Samples
Post-Closure Monitoring	TL-11A	1,1,1-Trichloroethane	200	ND	0	4
		1,1-Dichloroethane	20	**0.8**	4	4
		1,2-Dichloroethane	5	ND	0	4
		Benzene	5	ND	0	4
		Chloroethane	20	ND	0	4
		cis-1,2-Dichloroethene	70	**3.7**	1	1
		Tetrachloroethene	5	**5.9**	4	4
		Total 1,2-Dichloroethene	70	**4.7**	4	4
		trans-1,2-Dichloroethene	100	ND	0	1
		Trichloroethene	5	**10**	4	4
		Vinyl Chloride	2	ND	0	4
	TL-13A	1,1,1-Trichloroethane	200	ND	0	4
		1,1-Dichloroethane	20	ND	0	4
		1,2-Dichloroethane	5	ND	0	4
		Benzene	5	ND	0	4
		Chloroethane	20	ND	0	4
		cis-1,2-Dichloroethene	70	ND	0	1
		Tetrachloroethene	5	ND	0	4
		Total 1,2-Dichloroethene	70	ND	0	4
		trans-1,2-Dichloroethene	100	ND	0	1
		Trichloroethene	5	ND	0	4
		Vinyl Chloride	2	ND	0	4
	TL-18A	1,1,1-Trichloroethane	200	ND	0	4
		1,1-Dichloroethane	20	ND	0	4
		1,2-Dichloroethane	5	ND	0	4
		Benzene	5	ND	0	4
		Chloroethane	20	ND	0	4
		cis-1,2-Dichloroethene	70	ND	0	1
		Tetrachloroethene	5	ND	0	4
		Total 1,2-Dichloroethene	70	ND	0	4
		trans-1,2-Dichloroethene	100	ND	0	1
		Trichloroethene	5	ND	0	4
		Vinyl Chloride	2	ND	0	4
	TL-25A	1,1,1-Trichloroethane	200	ND	0	4
		1,1-Dichloroethane	20	ND	0	4
		1,2-Dichloroethane	5	ND	0	4
		Benzene	5	ND	0	4
		Chloroethane	20	ND	0	4
		cis-1,2-Dichloroethene	70	ND	0	1
		Tetrachloroethene	5	ND	0	4
		Total 1,2-Dichloroethene	70	ND	0	4
		trans-1,2-Dichloroethene	100	ND	0	1
		Trichloroethene	5	ND	0	4
		Vinyl Chloride	2	ND	0	4
	TL-26A	1,1,1-Trichloroethane	200	ND	0	4
		1,1-Dichloroethane	20	**3.3**	4	4
		1,2-Dichloroethane	5	**1.2**	2	4
		Benzene	5	ND	0	4
		Chloroethane	20	ND	0	4
		cis-1,2-Dichloroethene	70	**1.1**	1	1

Table 4
2018 Groundwater Volatile Organic Compounds Results
City of Tacoma Landfill
Tacoma, Washington

Program	Location	Analyte	Performance Standard (µg/L)	Maximum Detection (µg/L)	No. of Detections	No. of Samples
Post-Closure Monitoring	TL-26A	Tetrachloroethene	5	**4.4**	2	4
		Total 1,2-Dichloroethene	70	**2.2**	2	4
		trans-1,2-Dichloroethene	100	ND	0	1
		Trichloroethene	5	**5.1**	2	4
		Vinyl Chloride	2	ND	0	4
	W-03R	1,1,1-Trichloroethane	200	ND	0	4
		1,1-Dichloroethane	20	**0.5**	1	4
		1,2-Dichloroethane	5	ND	0	4
		Benzene	5	ND	0	4
		Chloroethane	20	ND	0	4
		cis-1,2-Dichloroethene	70	ND	0	1
		Tetrachloroethene	5	ND	0	4
		Total 1,2-Dichloroethene	70	ND	0	4
		trans-1,2-Dichloroethene	100	ND	0	1
		Trichloroethene	5	ND	0	4
		Vinyl Chloride	2	ND	0	4
	W-05	1,1,1-Trichloroethane	200	ND	0	4
		1,1-Dichloroethane	20	**2.6**	4	4
		1,2-Dichloroethane	5	**2.3**	4	4
		Benzene	5	ND	0	4
		Chloroethane	20	ND	0	4
		cis-1,2-Dichloroethene	70	**1.1**	1	1
		Tetrachloroethene	5	ND	0	4
		Total 1,2-Dichloroethene	70	**1.4**	4	4
		trans-1,2-Dichloroethene	100	ND	0	1
		Trichloroethene	5	**1.1**	4	4
		Vinyl Chloride	2	**0.5**	4	4
	W-10	1,1,1-Trichloroethane	200	ND	0	4
		1,1-Dichloroethane	20	ND	0	4
		1,2-Dichloroethane	5	ND	0	4
		Benzene	5	ND	0	4
		Chloroethane	20	ND	0	4
		cis-1,2-Dichloroethene	70	**0.5**	1	1
		Tetrachloroethene	5	ND	0	4
		Total 1,2-Dichloroethene	70	**0.6**	1	4
		trans-1,2-Dichloroethene	100	ND	0	1
		Trichloroethene	5	**0.5**	2	4
		Vinyl Chloride	2	ND	0	4
	W-16	1,1,1-Trichloroethane	200	ND	0	3
		1,1-Dichloroethane	20	ND	0	4
		1,2-Dichloroethane	5	ND	0	4
		Benzene	5	ND	0	4
		Chloroethane	20	ND	0	4
		cis-1,2-Dichloroethene	70	**1.2**	1	1
		Tetrachloroethene	5	ND	0	4
		Total 1,2-Dichloroethene	70	**1.6**	4	4
		trans-1,2-Dichloroethene	100	ND	0	1
		Trichloroethene	5	ND	0	4
		Vinyl Chloride	2	**0.5**	4	4

Table 4
2018 Groundwater Volatile Organic Compounds Results
City of Tacoma Landfill
Tacoma, Washington

Program	Location	Analyte	Performance Standard (µg/L)	Maximum Detection (µg/L)	No. of Detections	No. of Samples
Rebound Monitoring	TL-22A	1,1,1-Trichloroethane	200	ND	0	4
		1,1-Dichloroethane	20	**0.8**	3	4
		1,2-Dichloroethane	5	ND	0	4
		Benzene	5	ND	0	4
		Chloroethane	20	ND	0	4
		cis-1,2-Dichloroethene	70	ND	0	1
		Tetrachloroethene	5	ND	0	4
		Total 1,2-Dichloroethene	70	ND	0	4
		trans-1,2-Dichloroethene	100	ND	0	1
		Trichloroethene	5	ND	0	4
		Vinyl Chloride	2	ND	0	4
	TL-26B	1,1,1-Trichloroethane	200	ND	0	4
		1,1-Dichloroethane	20	**2.4**	4	4
		1,2-Dichloroethane	5	**1.4**	2	4
		Benzene	5	ND	0	4
		Chloroethane	20	ND	0	4
		cis-1,2-Dichloroethene	70	ND	0	1
		Tetrachloroethene	5	**3.7**	2	4
		Total 1,2-Dichloroethene	70	**1.4**	2	4
		trans-1,2-Dichloroethene	100	ND	0	1
		Trichloroethene	5	**4.1**	2	4
		Vinyl Chloride	2	**0.2**	1	4
	W-01R	1,1,1-Trichloroethane	200	ND	0	4
		1,1-Dichloroethane	20	ND	0	4
		1,2-Dichloroethane	5	ND	0	4
		Benzene	5	ND	0	4
		Chloroethane	20	ND	0	4
		cis-1,2-Dichloroethene	70	**0.9**	1	1
		Tetrachloroethene	5	**0.5**	1	4
		Total 1,2-Dichloroethene	70	**1**	3	4
		trans-1,2-Dichloroethene	100	ND	0	1
		Trichloroethene	5	**1.9**	4	4
		Vinyl Chloride	2	ND	0	4
	W-02	1,1,1-Trichloroethane	200	ND	0	4
		1,1-Dichloroethane	20	**1.1**	4	4
		1,2-Dichloroethane	5	ND	0	4
		Benzene	5	ND	0	4
		Chloroethane	20	ND	0	4
		cis-1,2-Dichloroethene	70	**1.8**	1	1
		Tetrachloroethene	5	**4.5**	3	4
		Total 1,2-Dichloroethene	70	**2.6**	4	4
		trans-1,2-Dichloroethene	100	ND	0	1
		Trichloroethene	5	**3.6**	4	4
		Vinyl Chloride	2	**0.3**	3	4
	W-04	1,1,1-Trichloroethane	200	ND	0	4
		1,1-Dichloroethane	20	**1.1**	4	4
		1,2-Dichloroethane	5	ND	0	4
		Benzene	5	ND	0	4
		Chloroethane	20	ND	0	4
		cis-1,2-Dichloroethene	70	**0.7**	1	1

Table 4
2018 Groundwater Volatile Organic Compounds Results
City of Tacoma Landfill
Tacoma, Washington

Program	Location	Analyte	Performance Standard (µg/L)	Maximum Detection (µg/L)	No. of Detections	No. of Samples
Rebound Monitoring	W-04	Tetrachloroethene	5	ND	0	4
		Total 1,2-Dichloroethene	70	**0.8**	4	4
		trans-1,2-Dichloroethene	100	ND	0	1
		Trichloroethene	5	**1.3**	4	4
		Vinyl Chloride	2	ND	0	4
	W-08	1,1,1-Trichloroethane	200	ND	0	4
		1,1-Dichloroethane	20	ND	0	4
		1,2-Dichloroethane	5	ND	0	4
		Benzene	5	ND	0	4
		Chloroethane	20	ND	0	4
		cis-1,2-Dichloroethene	70	ND	0	1
		Tetrachloroethene	5	ND	0	4
		Total 1,2-Dichloroethene	70	ND	0	4
		trans-1,2-Dichloroethene	100	ND	0	1
		Trichloroethene	5	ND	0	4
		Vinyl Chloride	2	ND	0	4
	W-11	1,1,1-Trichloroethane	200	ND	0	4
		1,1-Dichloroethane	20	**0.5**	1	4
		1,2-Dichloroethane	5	ND	0	4
		Benzene	5	ND	0	4
		Chloroethane	20	ND	0	4
		cis-1,2-Dichloroethene	70	**0.5**	1	1
		Tetrachloroethene	5	ND	0	4
		Total 1,2-Dichloroethene	70	**0.5**	1	4
		trans-1,2-Dichloroethene	100	ND	0	1
		Trichloroethene	5	**0.6**	2	4
		Vinyl Chloride	2	ND	0	4
	W-15	1,1,1-Trichloroethane	200	ND	0	4
		1,1-Dichloroethane	20	**1.0**	4	4
		1,2-Dichloroethane	5	ND	0	4
		Benzene	5	ND	0	4
		Chloroethane	20	ND	0	4
		cis-1,2-Dichloroethene	70	**2.1**	1	1
		Tetrachloroethene	5	**1.9**	4	4
		Total 1,2-Dichloroethene	70	**4.2**	4	4
		trans-1,2-Dichloroethene	100	**0.8**	1	1
		Trichloroethene	5	**1.3**	4	4
		Vinyl Chloride	2	**0.4**	3	4
	W-18	1,1,1-Trichloroethane	200	ND	0	4
		1,1-Dichloroethane	20	ND	0	4
		1,2-Dichloroethane	5	ND	0	4
		Benzene	5	ND	0	4
		Chloroethane	20	ND	0	4
		cis-1,2-Dichloroethene	70	**0.6**	1	1
		Tetrachloroethene	5	ND	0	4
		Total 1,2-Dichloroethene	70	**0.6**	1	4
		trans-1,2-Dichloroethene	100	ND	0	1
		Trichloroethene	5	**0.5**	2	4
		Vinyl Chloride	2	ND	0	4

Table 4
2018 Groundwater Volatile Organic Compounds Results
City of Tacoma Landfill
Tacoma, Washington

Program	Location	Analyte	Performance Standard (µg/L)	Maximum Detection (µg/L)	No. of Detections	No. of Samples
	W-22	1,1,1-Trichloroethane	200	ND	0	4
		1,1-Dichloroethane	20	**0.5**	1	4
		1,2-Dichloroethane	5	ND	0	4
		Benzene	5	ND	0	4
		Chloroethane	20	ND	0	4
		cis-1,2-Dichloroethene	70	**0.5**	1	1
		Tetrachloroethene	5	ND	0	4
		Total 1,2-Dichloroethene	70	**0.6**	3	4
		trans-1,2-Dichloroethene	100	ND	0	1
		Trichloroethene	5	**0.5**	2	4
		Vinyl Chloride	2	ND	0	4
	W-36	1,1,1-Trichloroethane	200	ND	0	1
		1,1-Dichloroethane	20	ND	0	1
		1,2-Dichloroethane	5	ND	0	1
		Benzene	5	ND	0	1
		Chloroethane	20	ND	0	1
		Tetrachloroethene	5	ND	0	1
		Total 1,2-Dichloroethene	70	ND	0	1
		Trichloroethene	5	ND	0	1
		Vinyl Chloride	2	ND	0	1

Notes:

ND = not detected
µg/L = micrograms per liter

Bold = detected concentration
Green Box = maximum detected concentration exceeds performance standard

Table 5
Summary of 2018 Sanitas Statistical Analysis Source Data
City of Tacoma Landfill
Tacoma, Washington

Analyte	Well	Sampled	Quarter	Groundwater Performance Standard	Early Warning Value	Result	Data Qualifier (a)	Sen Slope Trend (b)	Slope (ppb/yr)(b)
1,2-Dichloroethane (µg/L)	TL-04	2/9/18	2018 Q1	5.0	1.0	2.0			
		11/28/18	2018 Q4	5.0	1.0	1.7			
Tetrachloroethene (µg/L)	TL-11A	2/6/18	2018 Q1	5.0	1.0	5.9			
		5/8/18	2018 Q2	5.0	1.0	5.2			
		8/6/18	2018 Q3	5.0	1.0	5.9			
		11/27/18	2018 Q4	5.0	1.0	5.4			
	TL-26A	2/9/18	2018 Q1	5.0	1.0	4.4			
		11/27/18	2018 Q4	5.0	1.0	3.4			
Trichloroethene (µg/L)	TL-11A	2/6/18	2018 Q1	5.0	0.5	10			
		5/8/18	2018 Q2	5.0	1.0	9.7			
		8/6/18	2018 Q3	5.0	1.0	10			
		11/27/18	2018 Q4	5.0	1.0	9.5			
	TL-26A	2/9/18	2018 Q1	5.0	1.0	5.1			
		11/27/18	2018 Q4	5.0	1.0	4.2			
Vinyl Chloride (µg/L)	TL-07A	2/12/18	2018 Q1	2.0	0.5	1.7			
		5/10/18	2018 Q2	2.0	0.5	1.2			
		8/6/18	2018 Q3	2.0	0.5	1.1			
		11/30/18	2018 Q4	2.0	0.5	1.5			

Table provided by City of Tacoma

Notes:
(a) No data qualifiers
(b) No significant trends

Table 6
2018 Groundwater Extraction and Treatment System Outfall Analytical Results
City of Tacoma Landfill
Tacoma, Washington

Category	Analyte	Units	Discharge Limit[a]	Quarter 1	Quarter 2	Quarter 3	Quarter 4	
				2/13/2018	5/10/2018	8/6/2018	11/30/2018	12/11/2018
Field Parameters	Conductivity	µS/cm		283	317	321	179	25
	pH	pH Units		6.66	6.66	7.51	7.19	6.13
	Temperature	°F		48.8	57.5	59.9	51	46.4
	Turbidity	NTU		5.8	1 U	1 U	38.6	85
Metals	Iron	µg/L	1,500	**88**	**68**	**44**	--	**1,320**
	Iron, Dissolved	µg/L	1,500	--	--		--	**35.7**
	Manganese	µg/L	1,900	**410**	**346**	**241**	--	**120**
	Manganese, Dissolved	µg/L	1,900	--	--	--	--	**15.7**
Volatiles	1,1,1-Trichloroethane	µg/L	200	0.5 U	0.5 U	0.5 U	0.5 U	--
	1,1-Dichloroethane	µg/L	20	0.5 U	0.5 U	0.5 U	0.5 U	--
	1,2-Dichloroethane	µg/L	5	0.2 U	0.2 U	0.2 U	0.2 U	--
	Benzene	µg/L	5	0.5 U	0.5 U	0.5 U	0.5 U	--
	Chloroethane	µg/L	20	0.5 U	0.5 U	0.5 U	0.5 U	--
	cis-1,2-Dichloroethene	µg/L	70	--	--	--	0.5 U	--
	Tetrachloroethene	µg/L	5	0.5 U	0.5 U	0.5 U	0.5 U	--
	Total 1,2-Dichloroethene	µg/L	70	0.5 U	0.5 U	0.5 U	0.5 U	--
	trans-1,2-Dichloroethene	µg/L	100	--	--	--	0.5 U	--
	Trichloroethene	µg/L	5	0.5 U	0.5 U	0.5 U	0.5 U	--
	Vinyl Chloride	µg/L	2	0.2 U	0.2 U	0.2 U	0.2 U	--

Notes:

µS/cm = microSiemens per centimeter
µg/L = micrograms per liter
°F = degrees Fahrenheit
NTU = nephelometric turbidity units

U = The compound was undetected at the reported concentration.
Bold = Detected compound.

[a] Discharge limits for volatiles come from Table 8 of the Record of Decision (EPA 1988). Discharge limits for metals are not included in the ROD and were provided by the City of Tacoma.

Table 7
2018 Soil Vapor Analytical Results
City of Tacoma Landfill
Tacoma, Washington

Well Type	Sampling Location	PCE (µg/m^3)		TCE (µg/m^3)	
Extraction Wells	PW1b	**310**		**93**	
	PW1c	**370**		**88**	
	PW1d	**2,400**		**1,500**	
	PW2a	**150**		**140**	
	PW2b	**300**		**450**	
	PW2b (Dup 2)	**270**		**420**	
	PW3b	**760**		**690**	
	PW3c	**1,300**		**1,700**	
	PW3d	**1,800**		**1,600**	
	PW4a	**180**		**74**	
	PW4b	**130**		**63**	
	PW5a	**190**		**97**	
	PW5b	**1,100**		**280**	
	PW5c	**180**		**48**	
	S11	6.9	U	5.5	U
	S12	**54**		5.5	U
	S13	**73**		**37**	
	S14	**290**		**51,000**	
	S15b	**14**		**20**	
	S15c	**40**		5.5	U
	S15d	6.9	U	5.5	U
	S16a	**440**		**530**	
	S16b	69	U	55	U
	S16c*	69	U	55	U
	S17a	**170**		**160**	
	S17b*	34	U	**30**	
Perimeter Probes	PS01	**13**		**6.3**	
	PS01 (Dup 1)	**12**		5.5	U
	PS02	6.9	U	5.5	U
	PS03	6.9	U	5.5	U
	PS04	6.9	U	5.5	U
	PS66	**25**		5.5	U
	PS67	**18**		5.5	U
	PS68	**81**		**24**	

Notes:
1. Samples were collected on October 30 and 31, 2018, and analyzed by EPA Method TO-15.
Bold = detected concentration
U = non-detect
* Sampling locations are operational extraction wells (LAI 2018b); all other wells are currently non-operational.

Abbreviations/Acronyms:
µg/m^3 = micrograms per cubic meter
Dup = duplicate
EPA = US Environmental Protection Agency
PCE = tetrachloroethene
TCE = trichloroethene